AIR&SPACE

Smithsonian • December 1989/January 1990

Part helicopter, part airplane, the autogiro was in a class by itself

Having milked the cows and fed the calves... Margaret Dunbar is on her way to the office to open her mail.

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And ours.

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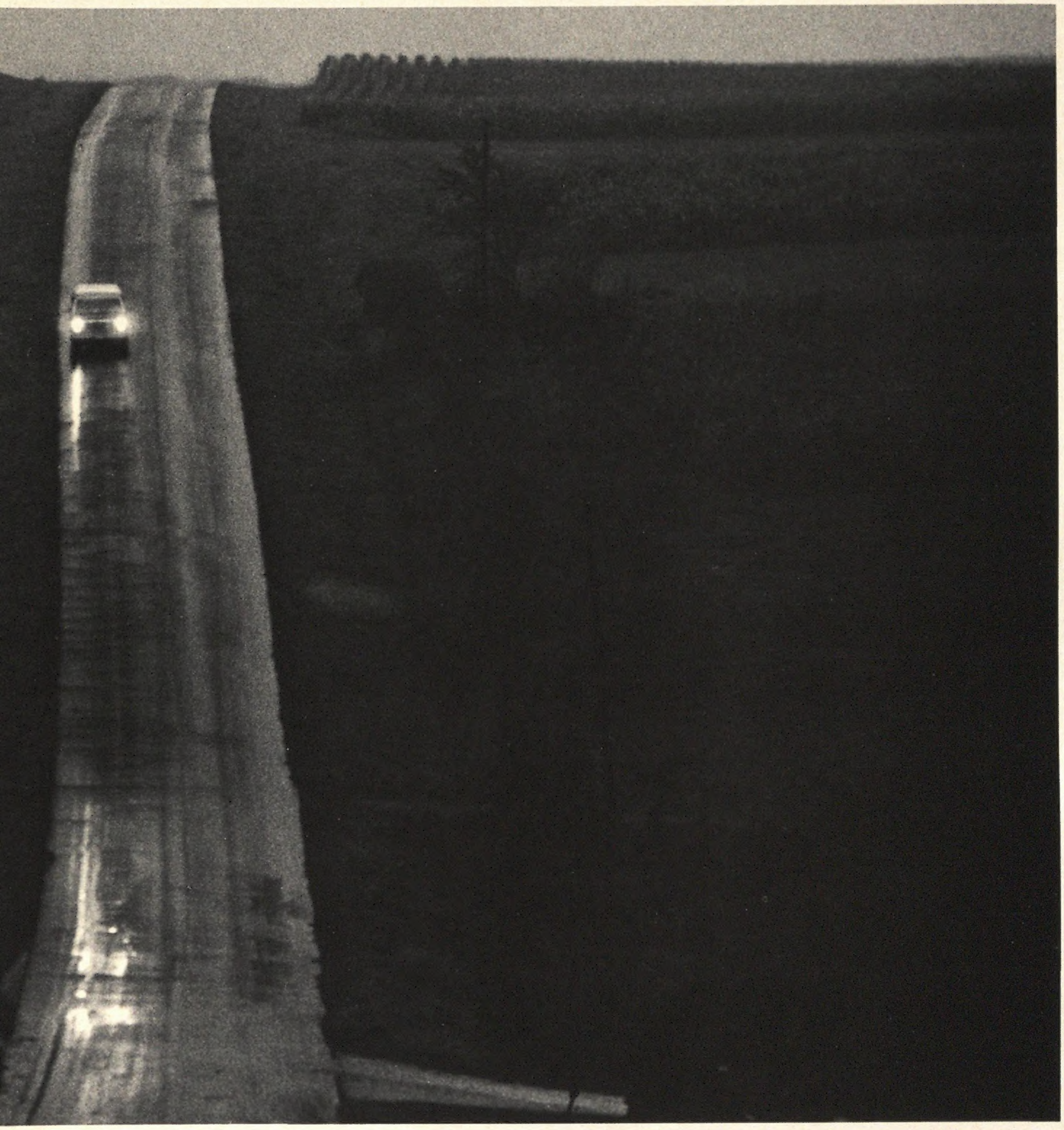

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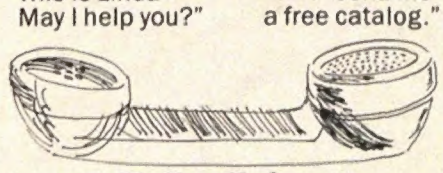

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December 1989/January 1990
Volume 4, Number 5

AIR&SPACE
Smithsonian

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Cover: *High above Depression-era New York City, an autogiro struts its stuff. (Courtesy NASM)*

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Amazing Space

One of the most amazing spaces I run across regularly is the magazine rack at the grocery store checkout counter. Here I can read all about the latest UFO sightings and other fantastic scenarios. My favorite headline was the one proclaiming that the moon is in fact the skull of a (large) alien creature that was stranded near Earth many eons ago. Really. Although I appreciate the entertainment value of such stories while standing in line, it distresses me to think that people take them seriously.

At the National Air and Space Museum we feature original artifacts of *genuinely* fantastic air and space exploits. Since the Museum was founded as the National Air Museum over 40 years ago, these exhibits have always been accompanied by a rich historical perspective. But some visitors have noted that the displays often lack physical or technical information. Last year the Smithsonian decided to address this area by establishing a new department in astrophysics.

Named the Laboratory for Astrophysics, the department will work with the curatorial and exhibit staff to bring to the public a deeper understanding of the universe and an appreciation of the state-of-the-art technology used to investigate it. The lab's astrophysicists will maintain their scientific expertise through a program that emphasizes active astronomical research. The department specializes in spectral analysis of cosmic sources of infrared radiation. Current research includes observations and modeling in four areas: the formation of stars from cold gas and dust in interstellar space, wind motions in the atmospheres of Venus and Mars, processes associated with explosive stellar outbursts known as novae, and the powerful energy sources in so-called "active" galaxies.

The staff is also actively developing new instruments. One major effort is devoted to testing optical parts for the Infrared Space Observatory, which is planned for launch in 1993. Our involvement in the development and use of this satellite marks the first time the Museum has been an active participant in a space venture, and we hope to incorporate this "insider's view" in future exhibits. A second program will develop a laser heterodyne spectrometer to measure wind velocities in the atmosphere of Titan, the largest moon of Saturn, from Earthbound telescopes.

Recently I was struck with a renewed sense of awe as I gave a talk on the unexpected discovery of symmetrical beams of material that shoot out of young stars forming in collapsing clouds of interstellar dust. I hope we can teach our visitors by capitalizing on the same spark of awe all of us feel the first time we comprehend some new aspect of our grand universe. In this technological age it is important that people realize that even complicated phenomena can be appreciated by everyone. Our younger visitors, who may be considering a career in space science or a related field, especially need to understand that our universe is comprehensible. Science can be made accessible, technology is not magic, and understanding enhances our appreciation. Even phenomena routinely analyzed by professionals can be awesome.

If we can sensitize our visitors to the "real stuff" in the Museum, perhaps they will come away more objectively critical of the bizarre stories that appear even in mainstream media and overcome our better judgment with repetition. While the tabloids appeal to our craving for the mysterious, the real world offers every bit as much drama—actually more, because editors have limited imaginations, but nature has no such constraints. Scientists have been trained to find fantastic scenarios in our world by careful observations and modeling of reality. This underscores a lesson on the value of basic research that I hope our visitors will take home—the importance of following our scientific noses while not knowing what discoveries await. Because by now scientists have learned to expect the unpredictable from our world of beautiful and amazing space.

—Howard A. Smith is chairman of the National Air and Space Museum's Laboratory for Astrophysics.

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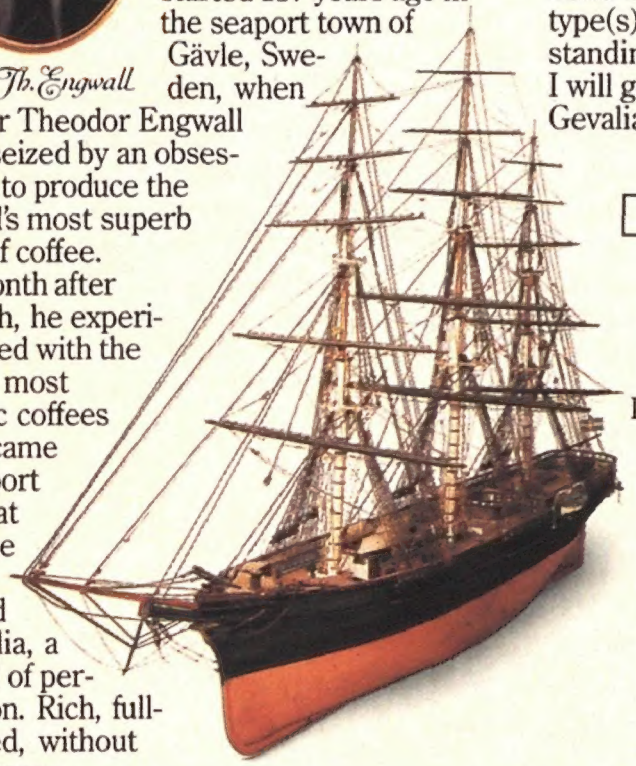

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Letters

Tuskegee Remembered

"The Flight of the Bumblebee" by Louis R. Purnell (October/November 1989) refers to a part of U.S. Air Force history that has been consistently omitted from the movie, TV, and written accounts of World War II. The exceptions include publications by black writers and a documentary produced by *Tony Brown's Journal* for PBS.

A significant result of the "Tuskegee Experiment" was that President Harry S. Truman recognized the federal government's responsibility to secure civil rights for all persons without regard to race, color, religion, or national origin. Outraged over the unjust treatment and segregation of black servicemen and women and heartened by the splendid combat record of the 332nd Fighter Group during the war, Truman issued Executive Order 9981 on July 26, 1948, barring segregation in the armed forces.

In 1976 those of us who had survived the Tuskegee experience organized Tuskegee Airmen, Inc., a non-military not-for-profit organization for the purpose of protecting the history of our group and encouraging the continued participation of financially disadvantaged youth in aviation and aerospace careers. We are grateful to you and Lou Purnell for the opportunity to be discovered or remembered.

Henry P. Hervey
Tuskegee Airmen, Inc.
Chicago, Illinois

Accolades to Mr. Purnell for his very personal and excellent story on the lengths to which he had to go to become a Bumblebee. I have nothing but respect for the contribution he and his fellow Bumblebees made to the victory in the air.

I was a fellow combat pilot in the 15th Air Force. We all knew of the black pilots who escorted us on missions over Nazi territory. We also knew they were a good, gung-ho bunch of pilots. They were always on time during a rendezvous and stayed right with us. They were there to protect us—and they did.

I recently visited Wright-Patterson Air Force Base. In a garden at the base there is a memorial to the Tuskegee airmen. It is a fitting memorial to a fine group of dedicated airmen. I salute them.

Lt. Col. Ben L. Donahue, USAF (Ret.)
Mountain View, California

Thank you for Louis R. Purnell's compelling and inspiring article. I continue to marvel at the fortitude and forbearance of our black citizens in the face of continuing discriminatory outrage. Mr. Purnell and his fellow Tuskegee airmen created a chapter in history that took too long to be revealed.

I feel both shame and pride—shame at the prejudice of my Caucasian heritage and pride in the accomplishments of blacks against awesome odds. I still hope in my lifetime to rid myself of the last vestiges of prejudice. I also hope to see the time when race will cease to be important and we will think only in terms of brothers and sisters.

James M. Fleming
Sedona, Arizona

Nuclear Power Yes!

Representative Brown's essay "Nuclear Power in Space: Balancing the Risks and

Benefits" (October/November 1989) is a typical example of political rhetoric designed to cloud the issue of the use and safety of nuclear power sources in space. His assertion that reactors are extremely dangerous to launch and that their only use in Earth orbit could be for weapons systems is extremely misleading.

Brown neglected to mention that of all the launches of U.S. nuclear-powered systems, only four experienced some form of failure and none released a significant amount of radioactivity into the environment. In fact, one radioisotope thermoelectric generator (RTG) was recovered from the ocean and eventually re-launched, testifying to the robust capability of the design to withstand launch failures. Another salient point is that, due to their lower fissile inventory, reactors pose a much smaller hazard during launch than do RTGs, such as those used on the Voyager, Viking, and Galileo missions. Certainly, after extended operation a nuclear reactor builds up an inventory of transuranic materials and fission products, but while contained in the reactor's core and when boosted to a suitable orbit, the materials pose no environmental threat. And although the ultimate disposal of these systems is currently under debate, it is by no means an insurmountable problem.

Despite Brown's implications, the use of nuclear reactors in Earth orbit is not limited to weapon systems. A nuclear reactor is no more a weapon than are batteries, fuel cells, or photovoltaic arrays. It is simply a component of a power system. Eliminating reactors from Earth orbit would needlessly obviate or limit a great number of potential civilian missions for which nuclear reactors represent an enabling or enhancing technology. Air traffic control radar satellites over the North Atlantic, highly efficient cargo transport via nuclear electric orbital transfer vehicles, free-flying manufacturing and processing platforms, and increased power capacity for the growth of the space station are but a few examples. These systems will enhance our capability to perform extended missions such as a lunar base or a manned Mars mission.

Obviously, no one wants reactors to re-enter Earth's atmosphere uncontrolled. But handicapping U.S. technology development because of what has been to this point solely a Soviet problem doesn't make much sense. If Brown wants to stop the deployment of weapon systems in space, he should work to find political solutions to the problems that call for these weapons. And if he really wants the U.S. to have the best civilian space program possible, he should work to increase its financial support so

NASA will not be forced to seek funding for its programs from sources such as SDI.

W.F. Lyon
Richland, Washington

More Controversy

"The Burnelli Controversy" (October/November 1989) is not only a libelous outrage but a disgrace to the Smithsonian, the keeper of historical aeronautical truths. In my opinion, the article was deliberately concocted to ridicule Burnelli and to attempt a character assassination of me personally.

I will not, at this time, attempt to detail all the inaccuracies, untruths, and distortions that appear throughout the article. However, I did not say that the military-industrial complex was "trying to kill the Burnelli concept." I said the complex had engaged in a diabolical conspiracy to kill the Burnelli Company in order to misappropriate the Burnelli concept from the public domain.

The recent appearance of the B-2 and the Douglas Mach 5 airliner, both of which embrace the Burnelli lifting-body philosophy, clearly demonstrates author David Noland's incompetence in the field of frontal area and wetted surface. Furthermore, Noland failed to mention the fact that the F-14, F-15, and F-18 are all derivatives of Burnelli jet fighters that were offered to the Pentagon in the late 1940's and early '50's.

Furthermore, Noland presented the Boeing 754/767 comparison totally out of context. In fact, the 754 offered double the payload, double the cubic capacity, and double the floor area of the 767.

The Northrop episode is equally distorted. The truth is that I was acting on the advice of legal counsel in a proper, business-like manner. The dishonorable Northrop behavior reflected the company's total disregard for the national interest.

On the personal side, I did not tell my former wife: "You are right, baby."

Noland falsely stated that I directed the quote in the penultimate paragraph of the article toward the establishment vice presidents of engineering. This was an absolute untruth, for that quote was taken out of my speech before the Niagara Frontier Aviation Hall of Fame, and it was directed toward the leaders of the military-industrial complex. What I really said was that I wished the vice presidents were present to openly debate the merits of the Burnelli design against the conventional design. This particularly applied to Boeing's W.H. Withington, who had already disgraced himself by writing a derogatory

letter on the Burnelli design to a Burnelli investor.

The so-called friend who suggested I should "simmer down" is obviously a wimp. How can any knowledgeable patriot ignore the truth of the Burnelli conspiracy, which cries out for urgent attention? In this regard, I quote Abe Lincoln: "To sin by silence, when we should protest, makes cowards of men."

Chalmers H. Goodlin
Miami, Florida

David Noland replies: I think Mr. Goodlin's real quarrel is with the sources at NASA, Boeing, Northrop, the Army, and other institutions who proffered their opinions.

On the subject of quotes: I read all of Goodlin's quotes back to him word for word during the preparation of the article. Two of the alleged misquotes he okayed. In the third case I made a minor change at his request. He had actually said, "My first wife told me, 'You love that airplane more than you love me.' I told her, 'You're right, baby. Goodbye.' " Goodlin asked that I eliminate the "goodbye." The quote from Goodlin's speech does in fact refer to "the industry," if not to the engineering vice presidents. In any case Goodlin okayed the quote as it appeared in the magazine.

After reading David Noland's Burnelli article I paid a visit to the New England Air Museum, where I was told that Burnelli's CBY-3 was not scheduled to be restored for another 15 years. I wonder if there will be anything left by then. It would be nice to drum up some support for a different ending to this saga.

Although I pride myself on my knowledge of airplanes, I wasn't aware of Burnelli and his incredible flying machines. I was impressed by his story and thank you for bringing it to a broader audience.

Charly Prevost
Studio City, California

Like Oil and Water

Regarding "Cheaper by the Dozens" (Soundings, October/November 1989), Marion County administrative officer Ken Roudybush should be advised that airports and landfills are not "a real compatible land use." Landfills attract birds, a hazard most aviators strive to avoid, particularly during approaches and departures. Numerous aircraft accidents have been attributed to birdstrikes and bird ingestion.

Karen S. Hawkins
Birmingham, Michigan

Cosmosphere Fan

Air & Space/Smithsonian is to be commended for the excellent article "Space Craft" in the August/September 1989 issue. I have visited the Kansas Cosmosphere and Space Center many times and have worked closely with its dedicated staff over the past seven years. I believe it is truly one of the outstanding museums in the country today. It has not gained the attention it deserves, possibly because of its rural Kansas setting, but thanks to this comprehensive article it will become better recognized for the national resource it has become.

Eugene A. Cernan
Houston, Texas

Coanda's Effect

"The Rises and Falls of Henri-Marie Coanda" (August/September 1989), mentioned that the Boeing YC-14 was the first of three airplanes to apply Coanda's principle of deflecting the flow of a turbofan aircraft engine. I was chief engineer on that airplane; how we came to use the Coanda Effect makes an interesting story.

The YC-14 was a competitor in the Air Force program for the Advanced Medium STOL (short-takeoff-and-landing) Transport. The specification called for a turbofan configuration that could operate from a 2,000-foot dirt field, allowing for an engine failure at the most critical time of both takeoff and landing. With a wing area selected for efficient cruise (there was a long-range requirement as well), a deflected thrust—or "powered lift"—scheme of some kind was necessary. For a variety of reasons, Boeing decided to go with a two-engine configuration.

At the time YC-14 development began, the most popular powered lift system was the Externally Blown Flap (EBF), in which a conventionally located (underwing) engine exhausts into the deflected trailing edge flap. The EBF concept had difficulties when applied to a twin, however. In order to keep the yawing moments due to engine failure as low as possible, the nacelles had to be close to the fuselage, leading to considerable aerodynamic interference and drag at cruise. Also, EBF was relatively inefficient at the large angles of thrust deflection needed for STOL landings.

In November 1971, I visited NASA's Langley laboratories to attend an aerodynamics conference. George Schairer, then Boeing's vice president of research and development, had mentioned to me that he thought some work was being done at Langley on blowing the engine exhaust over the top of the wing rather than under it, and that such a method might be more efficient.

Inquiries at Langley led me to NASA aerodynamicist Joe Johnson. He had just completed an applicable series of tests on a research model that he had "bootlegged" in a small wind tunnel scheduled for dismantling. It was readily apparent that the results were very favorable. Since the data wouldn't be published officially for months, I copied a pertinent example and returned to Seattle. Without this chance encounter, I believe the application of the Coanda Effect to aircraft powered lift would have remained hidden in the NASA archives for many years.

At Boeing, we quickly built wind tunnel models and performed our own tests, confirming Johnson's results. Boeing proposed our configuration in the formal Advanced Medium STOL Transport prototype competition in the spring of 1972; the system was dubbed "Upper Surface Blowing" (USB).

As expected, refining the configuration into a practical overall airplane took considerable effort. We placed a small movable door on the outboard edge of the nozzle to spread the exhaust flow better over the flaps while, at the same time, creating high-speed operation. Also, movable vortex generators were placed behind the nozzle to mix the flow and aid in turning it when the flaps were full down. The final result was the most efficient thrust deflection system ever devised at that time, showing 90 percent thrust recovery at 50 percent deflection. In addition, for every pound of thrust deflected the airplane gained two pounds of vertical force, the result of the "jet flap" effect on the surrounding airflow. The airplane could approach a landing at 86 knots with a wing loading of 85 pounds per foot, with all normal safety margins and only one engine operating. During flight tests, it was flown at speeds as low as 59 knots.

Making the Coanda Effect work in practice takes considerable finesse. But its turning efficiency is so high as to make future applications inevitable.

John K. Wimpress
Seattle, Washington

The Other Side

"The Legacy of Strategic Bombing" by David Savold (In the Museum, October/November 1989) mentions Heinz Knoke and his wife Lilo. You may be interested to know that Knoke was no ordinary pilot. Flying fighters from 1941 to October 1944, he survived bailouts and crashes and was eventually credited with 44 shoot-downs, including 19 four-engine bombers. (At the time I was flying aboard a B-17 in the Eighth Air Force.)

Knoke may have followed the wrong Pied Piper, but he was a brave man and much more than just a former Luftwaffe fighter pilot. One cannot even imagine the agony his wife Lilo must have suffered as her young husband flew and fought on the losing side.

John H. Kirkwood
Montesano, Washington

Who Came First?

Ben Bova made a small error in "To Mars and Beyond" (October/November 1989) when he says that Konstantin Tsiolkovsky was the first to propose solar sails. Jules Verne mentions "light as a source of motive power" in his 1865 *From the Earth to the Moon;* though this allusion is vague, an actual solar sail is described in the 1889 novel *The Extraordinary Adventures of a Russian Scientist.* In it a solar sail is to be launched on a mission to Venus from lunar orbit. It is given its initial boost by sunlight focused onto it from solar reflectors on the moon (not unlike Robert Forward's laser-propelled sails). The authors, Le Faure and Graffigny, describe their solar sail and its functions in some detail.

Another early solar sail is described in 1913 in the Russian novel *On the Waves of the Ether* by B. Krasnogorsky. Like the French sail, this one is also circular, with the manned cabin in the center.

Ron Miller
Fredericksburg, Virginia

Accident Report

While Stephan Wilkinson' s C-5 article ("Big," August/September 1989) was short on charity, its representation of my opinion of certain events was totally false. About the 1975 C-5 Babylift crash near Saigon, the article said "In fact . . . some—including the airplane's pilot—suspect the catastrophe was set off by a small shoulder-launched missile or an even more rudimentary weapon." I was the pilot. I suspect no such thing.

Col. Dennis Traylor
Maxwell Air Force Base, Alabama

Stephan Wilkinson repiles: I owe Colonel Traylor an apology and an explanation. I fell into the trap of listening to a C-5 pilot who claimed to know that Colonel Traylor believed the cause of his C-5 crash may have been a small missile rather than the loss of the pressure-bulkhead hinge. My mistake.

Air & Space/Smithsonian *welcomes comments from readers. Letters must be signed and may be edited for publication. Address correspondence to* Air & Space/Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024.*

A Little Traveling Music

Last September 29, on the anniversary of the *Discovery* liftoff that marked the shuttle's return to space, a celebration took wing in the theater of the Kennedy Space Center in Florida. Performing the first piece of music commissioned by the NASA art program in its 26-year history, composer and jazz saxophonist Jane Ira Bloom premiered *Rediscovery,* her musical impressions of the shuttle's flight. Leading a 26-piece orchestra, Bloom took the audience of 400 from liftoff to landing.

The 45-minute suite, in four movements, was a stylistic hodgepodge with a saving sense of humor. Bloom incorporated recordings of the sounds of an actual launch with synthesizer-produced pings and pops that evoked the void of space. Jazz and swing also surfaced, along with passages suggesting Holst's *Planets* suite and incidental *Star Trek* music. The piece concluded with a Sousa-like march. A kinetic performer, Bloom swayed her soprano sax up and down, to and fro, and at one point the entire brass section followed her lead, rising from their chairs and pirouetting while playing.

Along with six other artists commissioned by NASA, Bloom spent the three days prior to *Discovery*'s launch last year hanging around the Kennedy Space Center, absorbing its atmosphere, visiting the astronauts, and finally observing the launch. Bloom took in the lingo as well: "I can't tell you what a relief it is to light this candle," she told the audience after the concert, using the NASA jargon for ignition.

The painters in NASA's program also unveiled a dozen works that night, which join the 250 or so interpretations of NASA's history already on display at the spaceport. As did the prior work, the quality of the new varies—how many paintings of birds flying in the foreground as a shuttle lifts off can one appreciate?

But some rise above cliché. Dan Namingha's bright, elemental acrylics of the shuttle, influenced by his Hopi heritage, are prime examples. So is Angela Manno's *Self Discovery,* a batik and photo heat-transfer mandala with a generic astronaut in its center surrounded by aerial views of the Himalayas, all encircled by shuttlecraft. And Michael Knigin's *Cracking Wise* takes a welcome surrealistic Pop Art slant (attempts at high space art tend to trip over themselves).

Is NASA a suitable patron of the arts? Says NASA art program director Robert Schulman, "If art is about mystery or beauty or power, [artists] have come to the right place." But Bloom cautions: "Let's face it, NASA produces some of the best performance art in the world. It's a hard act to follow."

—Wes Eichenwald

Update

Air Guard Upgrade

A Michigan Air National Guard wing will make the transition from A-7s to F-16s much earlier than planned ("Old Gun," August/September 1988). All the mid-1960s vintage aircraft were grounded last April after a maintenance team discovered cracks around the trailing edge of an A-7 wing. After intensive inspections, 282 A-7s were found to be in need of repair. As a result, the 127th Tactical Fighter Wing at Selfridge ANG Base will get its F-16s in April 1990 instead of July 1992.

Star Search

The search for extraterrestrial intelligence (SETI) has been going on around the world for some 30 years. Now NASA is on the verge of inaugurating an intensive search via radio telescopes that will scan 10 million channels simultaneously. One survey will

What happens when an irresistible force meets an immovable object? When the force is an accelerating aircraft and the object is a million-pound concrete block, the force is obliterated. To demonstrate the integrity of nuclear reactor containment structures, Sandia National Laboratories in Albuquerque, New Mexico, sent a surplus F-4D fighter rocketing down a 2,000-foot sled with a 12-foot-thick concrete target at the terminus. The F-4 hit the target at 480 mph. The concrete suffered minor dents; fragments of the F-4, say Sandia researchers, were "found over a large area concentrated behind and to both sides of the target."

SANDIA

DAVID R. FRAZIER

Rush hour traffic in Boise, Idaho, came to a screeching halt, resulting in several minor collisions, when Hi-Way Implements launched its Case tractor balloon early one morning during the Western Idaho Fair last August. The motorists may have trouble convincing their insurance companies that they were distracted by a nine-story-tall red tractor flying over the highway.

search the sky in all directions; a second will focus on several hundred specific stars. Expectations are running high. Frank Drake, SETI Institute director, thinks there's a good chance of finding an intelligent signal within the next 10 years.

What should we do if that happens? "An unprepared civilization might not handle the situation well," says Michael Michaud, a science counselor with the state department. With that in mind, Michaud and an international group of scientists and scholars have drafted a set of guidelines to follow for verifying and announcing the discovery of extraterrestrial intelligence. The International Academy of Astronautics and the International Institute of Space Law are backing the protocol, and its authors hope to have it endorsed by members of the United Nations in 1992, the 500th anniversary of Columbus' discovery of America.

So when the call comes, does the discoverer sit on it or frantically call a press conference? According to the nine-point recommendations, neither reaction is appropriate. The guidelines stress the need to alert the international scientific community, which should assist in verifying that the signal is valid. The authors want to avoid the period of silence that followed the 1967 detection of pulsars, collapsed rotating stars that emit strong, rapid pulsations. Pulsars were thought at first to be too precise to be a product of nature. Fearful of sounding a false alarm, British radio astronomers kept their discovery quiet for months. "It's critical we get everyone looking at it," says Peter Boyce of the American Astronautical Society. "A premature announcement is akin to yelling 'Fire!' in a crowded theater."

If it turns out to be the real thing, the secretary general of the United Nations should be notified, and the news announced to the world—by the discoverer, if he or she wishes—at a press conference. All data should be made available to the scientific community, with copies permanently stored for further analysis. If the signal comes via radiowave, the policy urges U.N. signatories to enact an international agreement protecting that frequency. Furthermore, all procedures should be continually reviewed and an international committee established to analyze the evidence.

The declaration fails to address one crucial question: Do we respond? "That's a political, emotional, and philosophical issue for the world to decide," says Boyce. Consequently, the declaration states that no response will be made until "appropriate international consultations" have occurred. And that, the document states, will be the subject of a separate agreement—one that is perhaps years down the road.

In any case, "once you know where a signal came from, there is no way to ignore it," says NASA scientist and co-author Jill Tarter. "Even if the world decided not to respond, a group of individuals probably would do it anyway."

—Lori Keesey

BELL BOEING

Update

Tilt-rotor Transition

A Bell-Boeing V-22 Osprey prototype made the first full in-flight transition from helicopter mode to airplane last September (Flights & Fancy, February/March 1989). The two pilots also experimented with various speeds and engine nacelle angles during the hour-long flight at Arlington, Texas. Production of the aircraft is still the subject of a House-Senate budget battle.

Looking Hugo in the Eye

Hurricane Hugo, which savaged communities from the Antilles to the Carolinas this summer with 17-foot tides and 135-mph winds, also made an indelible impression on a small band of aviators and scientists who make their living by flying into hurricanes. On September 15, Hugo played hob with one of the research airplanes buzzing around in its maw.

NOAA 42 and 43, four-engine turboprop Lockheed Orions beefed up to National Oceanic and Atmospheric Administration specifications and used for atmospheric studies, took off from Barbados in the West Indies early that afternoon. NOAA 43 was to work the fringes of the storm; NOAA 42 would fly down the narrow avenues between bands of storm clouds that spiralled out from Hugo's eye. By 1:30 p.m., NOAA 42 had nearly penetrated the eyewall, a column of dense clouds surrounding the tranquil eye and the source of the worst winds. The crew was flying at only 1,500 feet, gathering data on the interaction between Hugo and the warm ocean that had spawned it.

Usually, an aircraft flying into a hurricane uses its radar to pick a relatively benign spot in the eyewall to cross. But that afternoon, says James McFadden, hurricane project manager at NOAA's Aircraft Operations Center in Miami, the Orion punched through an eyewall segment that glowed with ugly intensity on radar. "It looked like the kind of thing you don't want to penetrate," he recalls.

NOAA 42 was only a few hundred feet of hard flying from the eye when Hugo's winds suddenly started pummeling the airplane. Like a toy gripped by a rampaging baby, the Orion was whipped back and forth sideways, then up and down as the winds shot up past 180 knots.

The heavy side loads and vertical motion created bedlam in the cabin. "We've always stored things like briefcases and stuff behind seats and bulkheads," McFadden says. "With the side jolts, all that stuff came into the aisle. Then when the strong up-and-down motion hit, the stuff went everywhere. It looked like someone had come in and trashed your house. A 20-man life raft just slid out from under its straps into the aisle and began flying around in there—this big yellow thing coming at you . . . . It put a big dent in the overhead handrail."

The sudden G-loading was only part of the excitement. "At about the same time we got hit with the big jolts," McFadden says, the right-hand inboard engine "decided to take a vacation." The problem was later traced to a malfunction in the fuel control system that may have been induced by the sudden shaking.

According to McFadden, the whole thing, from the sudden turbulence in the eyewall to breaking into the calm eye, took less than a minute. "We had about 30 seconds there that seemed like two weeks." But by the time the airplane was tossed into the eye, it had lost half its altitude—roiling gray water was only about 800 feet below. "It was early in the mission and we were heavy," McFadden explains, "so we had to begin trying to climb and dump about 12,000 pounds of fuel in the eye." For the hour it took NOAA 42 to labor to 9,000 feet, the crew flew without radio contact—when fuel is dumped, all electrical equipment must be shut down.

Meanwhile, NOAA 43, on the storm's outskirts, turned in to monitor its troubled sister ship. Things got cozy in the 12-mile-wide eye when an Air Force Lockheed WC-130 hurricane hunter joined them, maintaining its minimum penetration altitude of 10,000 feet.

"The problem was keeping our airplane in the eye while we circled," McFadden says. But there was no thought of ditching. "Even in the eye, there are lots of standing waves. We don't carry parachutes for the same reason."

Was that the roughest hurricane ride in memory? "We've been tossed around before," McFadden says. The worst ride he recalls is a flight into 1971's hurricane Edith. "We got stomped—but we were at 10,000 feet." He adds, "Also, we never lost an engine right in a storm before."

After its long hour in Hugo's eye, NOAA 42 slipped out through a less refractory part of the eyewall and flew back to Barbados. When Lockheed inspectors arrived to examine the 14-year-old aircraft, they found no damage beyond a few cracks that could not be definitely tied to the storm. A few days later, the Orion was back in Miami for a scheduled overhaul. And its crew was back in hurricane Hugo, working the big whirlwind all the way to its devastating South Carolina landfall.

—Carl A. Posey

Update

New Hope for the ISF

The Industrial Space Facility is rolling with the punches, according to Space Industries president Joseph Allen ("Space Stations in Lobbyland," December 1988/January 1989). Allen says his company may revive the ISF as a space station "outbuilding" if cost and engineering changes force a shrinking of the space station design.

A small satellite earth station, capable of simultaneously receiving voice, video, and digital data information, allows companies to reduce their communications costs. The Hughes Aircraft Company Personal Earth Station™ uses patented demand-assigned, packet-switched transmission techniques, in which different types of information are transmitted over a single communications channel as small, high speed data packets. Other types of communications systems require expensive, separate channels for voice, video and digital data information. The earth stations are part of Hughes' Very Small Aperture Terminal network, which provides end-to-end satellite communications for private business data networking and videoconferencing.

A new packaging technology offers the highest circuit interconnect density per unit volume in applications ranging from digital to microwave. Developed by Hughes, the technology, called low-temperature cofired ceramic packaging, places buried interconnects, such as low frequency signal traces and RF stripline, in laminated ceramic material. Buried passive elements, such as resistors and capacitors, can also be incorporated into this monolithic package structure. High packaging density is also achieved by placing devices into cavities and interconnecting within the cavity walls. This new technology offers significant weight and size reductions in several applications, especially active radar antennas.

A diamond film deposition system that allows an exceptionally high degree of control over the film deposition process has been demonstrated by Hughes. The system successfully deposited small polycrystalline diamond islands on a silicon substrate at temperatures below 200 degrees Centigrade. This overcomes a principal impediment to diamond-film applications, namely the lack of a way of depositing quality films at reasonably low temperatures. Thin films of diamond can serve a wide variety of applications because of their hardness, infrared transparency, high thermal conductivity, and high temperature operation. In addition, their excellent semiconductor properties promise performance superior to gallium arsenide.

A new generation of high-speed milling machines and machining technology reduces the time required to make radar antenna assemblies by 700 percent. The computer-based machines, developed by Hughes and Matsuura Machinery Corp., operate with 100,000 revolution per minute spindle speeds and 200 to 600 inch per minute material feed rates. At these speeds, only 900 hours are required to machine assemblies that require 6,700 hours with older generation milling equipment and technology. The machines are also equipped with an integral probe that measures critical dimensions during the milling process and verifies that they are within specifications, eliminating the need for time consuming off-line inspection of every part.

Hughes' Combat Systems Engineering Facility in San Diego, California has immediate openings in advanced development and training to support the Navy Command and Control Processor (C2P) and Advanced Combat Direction System (ACDS) Programs. Experience desired for Combat Systems Engineers includes 7-9 years of system level development of military systems, preferably Surface Navy Combat Systems. For Computer Programmers/Instructors the level of experience desired is 4-5 years of designing, coding and debugging computer software. Teaching or training experience is desired. Applicants must have a B.S. Degree in Computer Science or the equivalent. Please send your resume to Hughes Aircraft Company, Ground Systems Group, Dept. S4, P.O. Box 4275, Fullerton, CA 92634. Equal opportunity employer. U.S. citizenship required.

For more information write to: P.O. Box 45068, Los Angeles, CA 90045-0068

HUGHES

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Update

A Better Look Before They Leap

Ejection-rated night-vision goggles may eventually assist aviators forced to eject from stricken aircraft ("Chariots of Fire," April/May 1989). ITT Defense in Roanoke, Virginia, hopes to have its lightweight, compact NVG at an Air Force medical research lab for testing by January 1990. Current NVGs are too ungainly for high-speed ejections.

Airport Makeover

Bar Nunn, Wyoming, no longer has an airport. It still has three runways, but now they serve as broad thoroughfares for the town's 725 residents.

In 1953 longtime resident Romie Nunn bought what was left of Wardwell Field—600 acres, six miles of runways and taxiways, and a hangar—on a whim. The Army Air Forces had abandoned Wardwell in 1942 for nearby Casper Army Airfield (now Natrona County International) and its 10,600-foot runway. "They put the airport up for bid and he got it," says Nunn's 82-year-old widow Margaret, "and then he didn't know what to do with it."

Eventually Nunn came up with a plan for the Bar Nunn Ranch subdivision. "Everybody was going to have five or six acres," recalls town councilman Roger Hill, "and they could land an airplane in their front yard and have horses in the backyard. He was going to put a riding path all around the airport."

Nunn created a Bar Nunn brand and did have a riding ring in the hangar for a while. But the horses and airplanes never materialized. The Bar Nunn Ranch attracted only about a hundred houses and trailer homes, and despite a mini-oil boom in the 1970s lay more or less fallow for some 20 years, except for a brief flurry of activity in 1968 when the airport doubled as a Venezuelan strip for the John Wayne movie *Hellfighters*.

In 1982 residents voted to incorporate as a town to protect building standards and become eligible for state and county funding. They created a town seal based on the layout of the runways, which became Sunset Boulevard, Antelope Drive, and Palomino Avenue. A 20-foot-wide swath fronting the homes on each side of the runways was repaved for traffic (residents

hope to eventually place medians full of trees and shrubbery down the runway centerlines). The deteriorating hangar, with its faded "Wardwell Field Elev 5282 ft." sign, went up for sale as storage space.

Despite the traffic, houses, phone poles, and pedestrians, Bar Nunn still resembles an airport, at least from the air. Connie Petty recalls approaching Natrona County International, just two miles west of Bar Nunn, in an airliner, and thinking, *Well, look at that. It looks just like an airport.* "And then I realized it was my town and my house was over there," she says.

Other fliers have been similarly confused. In 1983 one landed on Antelope Drive and another set down on Palomino Avenue. "The reason he gave the police for landing was that he had landed here 43 years ago," says planning board chairman Jerry Petty. "The other one landed because he lost part of his propeller." No one's dropped in on Bar Nunn since, but fire chief Chuck Johnson notes that "when you back out of your driveway, you have to look right, left, and up."

—Bob McCafferty

Update

Commercial Launch a Loss

American Rocket Company's $2 million booster burned up on the launch pad during AMROC's first attempted liftoff from California's Vandenberg Air Force Base on October 5 ("The California Rocket Race," December 1987/January 1988). An AMROC official says a second suborbital launch attempt may be made in 1990.

Anniversaries . . .

1610
January 7 Galileo discovers Io, Europa, Ganymede, and Callisto, the four largest of Jupiter's 16 moons.

GEOFF CHESTER

Galileo recorded his observations in Sidereus Nuncius *(The Starry Messenger).*

1917
January 16 The greatest World War I flying ace, Manfred von Richthofen—better known as the Red Baron—is awarded the Ordre pour le Mérite, or "Blue Max," by William II, the king of Prussia, for his 16th aerial victory. Six months later Richthofen was shot down and received a head wound that required three months of convalescing. Plagued by nightmares and headaches, he could have taken an administrative post, but Richthofen returned to flying, eventually shooting down a total of 80 Allied aircraft. He wrote in his memoirs, "I would become miserable if now, honored with glory and decorations, I became a pensioner of my own dignity in order to preserve my precious life for the nation while every poor fellow in the trenches endures his duty exactly as I did mine."

1918
December 17 The Aero Club of America announces that aviators certified as "expert" pilots are permitted to fly over cities. By this time "aeroplanes" had achieved a range of 1,000 miles and could carry loads of 1,000 pounds at speeds of 138 mph. The club's board of governors predicted that airplanes would become a popular mode of transportation, and they hoped that removing the ban on over-city flights would encourage more people to fly. To qualify for an expert's certificate, an aviator had to pass a "severe physical examination" as well as complete three flight tests: a 25-mile cross-country flight, an unpowered glide from 2,500 feet, and a figure eight.

1919
January 19 Jules Vedrines, a veteran of World War I, lands a biplane on the roof of a Paris department store, the Galeries Lafayette. Later in the day Vedrines announced his plans to fly around the world. The Frenchman told reporters, "I couldn't sleep a wink last night. I was not nervous about the stunt itself, of course, but I was so afraid that those darned police would get wind of it and stop the whole business." Eleven days later they did: police stopped Vedrines from taking off from the store's roof. The biplane was taken apart and removed by elevator.

At the age of 25, the Red Baron was shot down and killed behind British lines.

NASM

1924
December 21 At a press conference Judge Charles H. Anderson of Croton, New York, expresses his opinion that there may be an "airtrap" over his town that caused three aircraft to fall suddenly. In the first incident, an airplane smuggling liquor from Canada crashed; a year later an airplane carrying two men and three women dove into the Hudson. Then Samuel H. Turner and his airplane fell 2,000 feet before regaining level flight. In all three incidents the aviators sustained only minor injuries.

1925
January 15 Charged with illegally parking his car on Madison Avenue, Cyril Turner, a 35-year-old skywriter, appears before magistrate Moses R. Ryttenberg in New York City's traffic court. When Turner told the court that his profession was skywriting, Ryttenberg asked, "What's that?" "I'm an aviator, and I write advertising in the sky with smoke from an apparatus on my airplane," replied Turner. "Well," said the magistrate, "inasmuch as you're the first member of that profession to be brought before me, I'll suspend sentence."

1926
December 27 W.J. Barrows, a pilot with Ryan Airlines of San Diego, is marooned on a snow-covered mountaintop in Mexico with no food or emergency supplies, only a load of beer. Barrows survived on barreled beer for 72 hours in an open-cockpit monoplane. He and two other Ryan pilots had begun airlifting beer when heavy snowstorms closed the road leading from a Mexicali brewery to Tijuana. The brewery, unable to arrange alternate routing through the United States, was frantic to get its product to the taverns of Tijuana for the Christmas holiday season, so it struck a quick deal with Ryan Airlines. After melting snow permitted Barrows to leave Mexico, he landed in Los Angeles in good health.

NASM

Dick Bong, the leading U.S. ace of all time, shot down 40 Japanese aircraft.

1927

January 3 Citing the fact that in 1926, 80 people in the state of Missouri were kicked to death by mules, while only eight commercial pilots lost their lives in aviation accidents, U.S. Army Air Service captain H.G. Stevens tells the American Society for the Promotion of Aviation that commercial aviation is safer than "playing around the business end of a mule."

January 18 The Royal Air Force recommends chewing gum to its pilots as an "aid to descents." According to the RAF training manual, chewing gum is useful for keeping the throat from becoming parched during rapid descents and helps fliers equalize air pressure inside their ears.

1929

December 14 A Ford Tri-motor carrying six passengers over the Andes mountains in South America collides with a condor. "The bird spotted us, wheeled around and came over as if it had said, 'Let's see what this is all about,' " said pilot L.H. Garriott. "I swerved the ship a little and just in time. With a sound like a shot, he hit the wing and dropped." After landing, Garriott found a feather-covered dent in one wing; passengers walked away with the feathers as souvenirs.

December 29 Five men in an airplane make a forced landing on Lake Flower in Saranac Lake, New York. The group had set out from the Curtiss-Wright hangar at Lake Placid earlier in the day for a sightseeing trip. Though skies were clear when the men left, they soon encountered a snowstorm, and after flying for an hour with poor visibility, pilot Frank Reed decided to land. The airplane came down on the frozen lake and rolled a short distance before plunging through the thin ice. As the aircraft began to sink, its occupants jumped to the safety of nearby ice floes.

1944

December 17 Flying over the Philippines, Major Richard I. Bong, the top-scoring American ace, scores his final aerial victory. Throughout his World War II career, Bong shot down a total of 40 Japanese aircraft. In a newspaper interview Bong said of his job as a fighter pilot: "There are no bright lights and music and most of the time you're at a forward base with nothing but mosquitoes and movies to entertain you. It's a grim and tiresome profession, relieved only occasionally by a really good scrap." Fearful that the United States would lose its premier pilot, Air Force officials had Bong awarded the Congressional Medal of Honor and removed from combat duty. Eight months later the 24-year-old Bong died when the Lockheed P-80 jet fighter he was testing crashed.

NASM

Rigorous testing of the Comet design did not prevent metal fatigue in early models.

1954

January 10 The de Havilland Comet that inaugurated the world's first passenger jet commercial service in 1952 breaks up in midair and crashes into the Mediterranean, killing all 35 people aboard. The airliner, a British Overseas Airways Corporation jet on a flight from Rome to London, fell from clear skies 30 minutes after takeoff. By the end of March most of the wreckage had been brought up from the sea, and after British officials painstakingly reassembled the Comet, they determined that a structural failure occurred because cabin pressurization had caused metal fatigue, which in turn resulted in a fracture.

1988

December 1 A technician readying a Boeing rocket for launch aboard the space shuttle slips on the hem of his lab coat and bangs into the rocket's first stage, leaving a four-inch crack in the exhaust nozzle. The entire first stage had to be replaced at a cost of $6 million. Press coverage of the mishap omitted the technician's name, sparing him public humiliation.

. . . and Events

December 2–December 31
"Steichen and His Men: A Photographic Portrait of World War II." Smithsonian Traveling Exhibition. At USS *North Carolina* battleship, Wilmington, NC, (919) 762-1829.

December 2–January 14
"Superman: Many Lives, Many Worlds." Smithsonian Traveling Exhibition. At Philbrook Art Center, Tulsa, OK, (918) 749-7941.

December 11 & 12
Aviation Law Operations and Claims Conference. This year's event includes industry speakers and panelists on air safety. At Churchill Hotel, Partman Square, London, England, telephone 01 486-5800.

December 17–January 21
"Black Wings: The American Black in Aviation." Smithsonian Traveling Exhibition. At African American Museum of Cleveland, OH, (216) 791-1700.

December 21
Solstice occurs at 4:22 p.m. EST, marking the beginning of winter in the northern hemisphere.*

**Call the Smithsonian's Earth and Space Report at (202) 357-2000 for recorded information on astronomical events.*

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Events will be listed as space allows.*

—Diane Tedeschi

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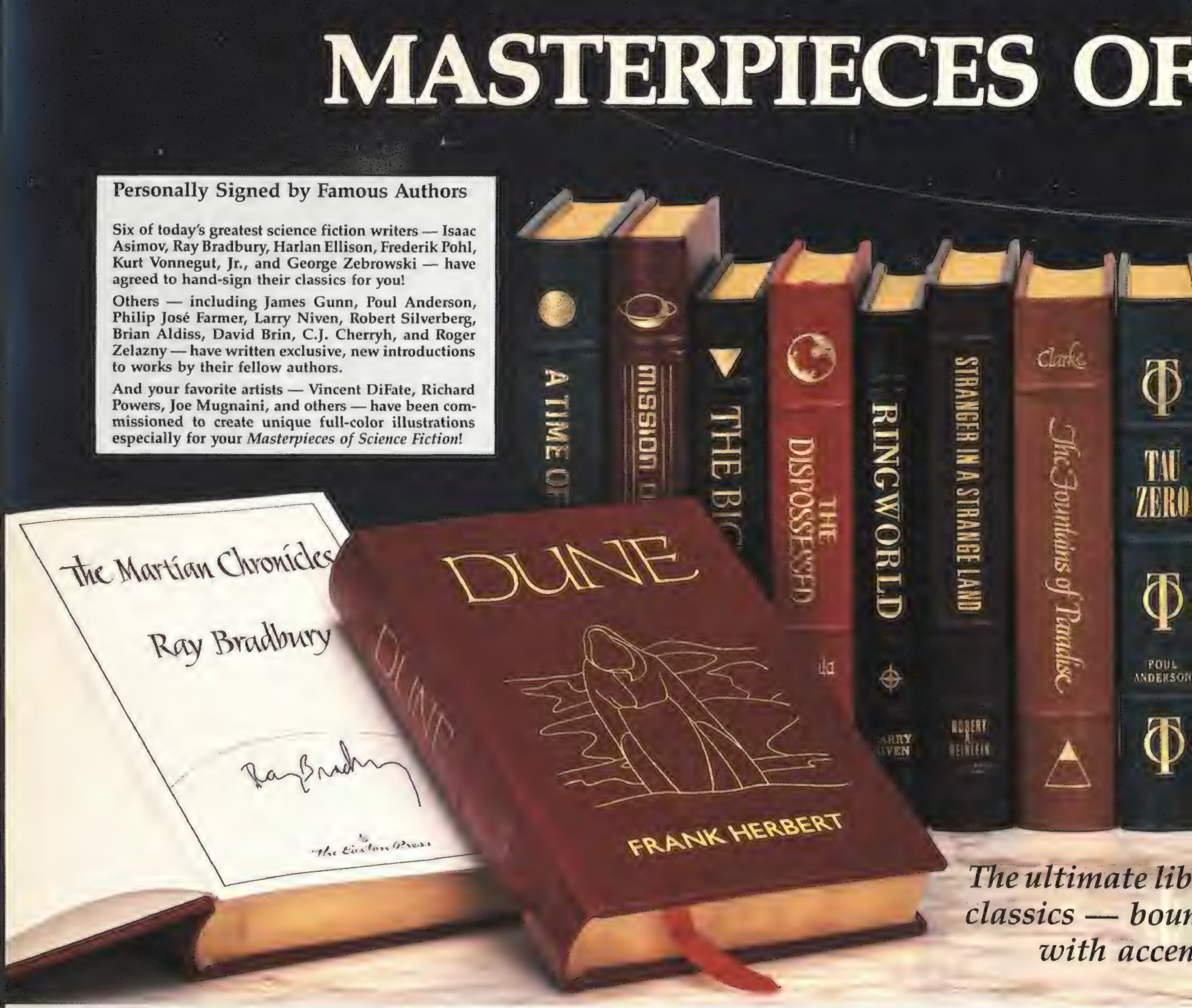

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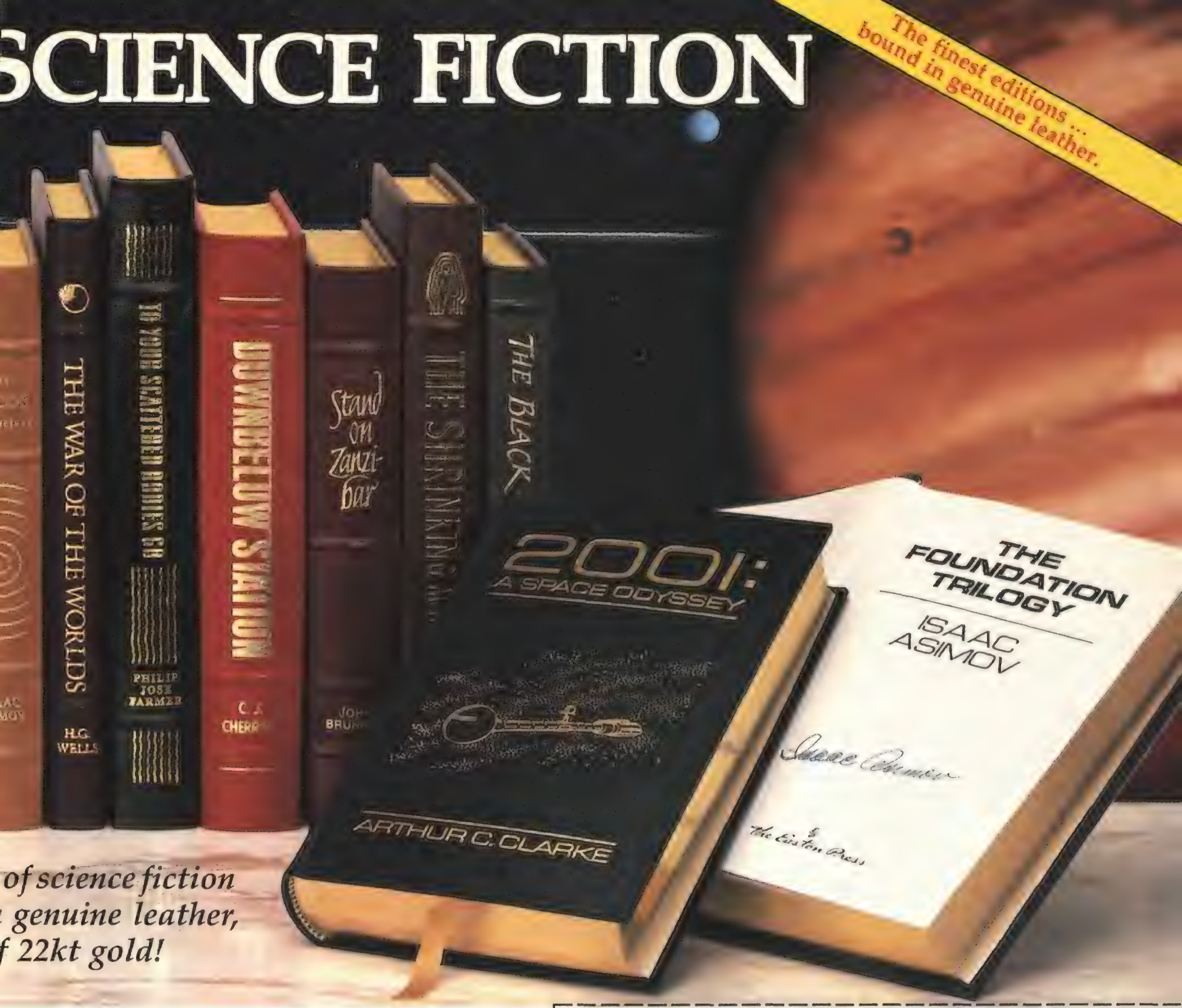

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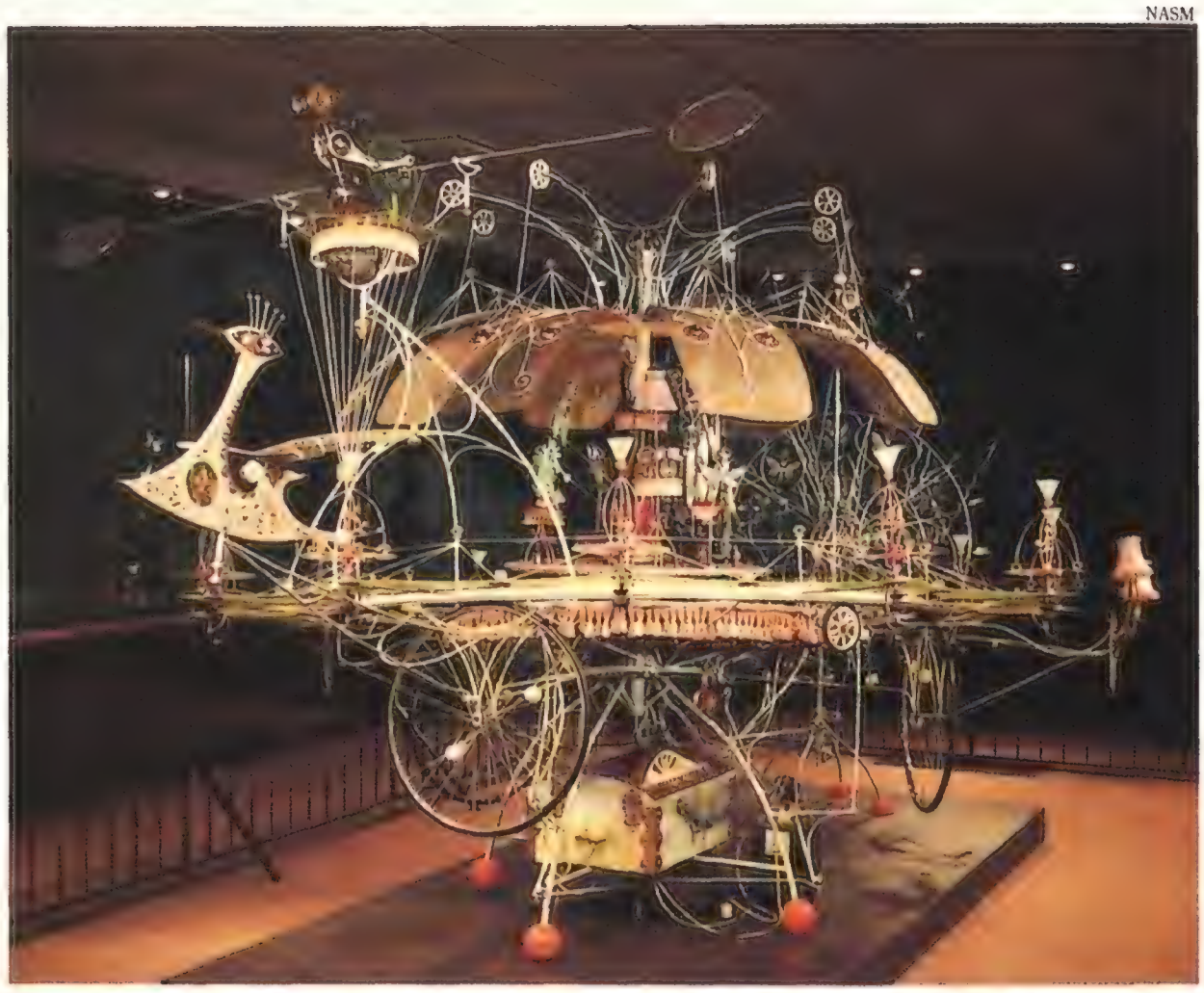


"S.S. Pussiewillow II" is designed for paddling along the Mississippi—in the clouds.

When plans were being drawn up for the National Air and Space Museum's current building, former director and ex-astronaut Michael Collins insisted that it include at least one of Rowland Emett's creations. The British artist's self-described "blindingly lucid explanation of extra-terrestrial goings-on" arrived shortly thereafter in the form of "Moon-probe Lunacycle MAUD." The Museum has never been the same.

Though the Lunacycle eventually moved on to other exhibit sites, it will return for an encore this December as part of an exhibit featuring Emett's work. "Too Late for the Past, Too Early for the Future: Drawings and Things by Rowland Emett (A Showing for Those Who May Have Missed Their First Appearance, or Who Were Not Actually Born at the Time)" is its exceedingly complete—and typically droll—title.

Since 1980 visitors to the Museum have been enjoying Emett's "S.S. Pussiewillow II." This three-dimensional marvel, a cross between a flying machine and a flying carpet that includes butterflies and tea cakes, was commissioned to fill the void left by the Lunacycle. "There was this uncomfortable feeling of being Emett-less," remembers Mary Henderson, the Museum's curator of art.

"When the Smithsonian got in touch with me was one of the high points of my life," says Emett. He is slim and remarkably spry for his 83 years, perhaps because of his daily swim in his pool. With his wife Mary, he lives at Wild Goose Cottage, their house-*cum*-atelier in Ditchling, Sussex, in England. But heart trouble has recently convinced Emett that it would be wise to move permanently to London after 37 years in Sussex.

Emett's interest in flying machines stems in part from his work as a mechanical draftsman in aircraft design early in World War II. "I was edged by the government into a peculiarly hush-hush corner of aircraft design," he says, with the emphasis on "peculiarly." Originally Emett wanted to be a landscape artist; his painting "Cornish Harbour" hung in the Royal Academy Exhibition in 1931. But he needed money and went to work in a commercial drafting office instead. During the war his work began to appear regularly in the British humor magazine *Punch,* and it was there that Emett found an audience for what Henderson calls his "particularly whimsical and kind of phantasmagorical work."

Eventually Emett began transmuting his drawings into three-dimensional marvels. "The drawings always look as though it was impossible for them to work," Henderson says, "but in fact Emett has made them into machines that do work." Many Americans were introduced to Emett's work in *Chitty Chitty Bang Bang.* Eight of his machines are featured in the movie as inventions of the Dick Van Dyke character.

The Museum's exhibit will also include Emett's "Featherstone-Kite Openwork Basketweave Mark II Gentleman's Flying Machine," which was his first vision of man's arrival in space. "The machine is constructed of cane windbreaks from little-known French vineyards and the wings are supported upon willowy saplings," Emett explains in a catalog from London's Tate Gallery. "All major control surfaces are covered with wild silk, suitably tamed. Power is provided by a Wandering Hot-Air Brazier and a swarm of underslung silver butterflies provide a trivial lift to the nose section . . . . Main Wheels retract into semi-buoyant shrimplike nacelles and 'Eiffle' Altimeter gives those three heights every well-found pilot should know: Canal Level, OUR CHIMNEY, and Milky Way."

After the exhibit closes in December 1990, "S.S. Pussiewillow II" will stay on as a permanent keepsake of Emett's imagination. Its gallery is located not far

from Project Surveyor, an honest-to-God spacecraft that made a soft landing on the moon to survey potential Apollo landing sites. In their own ways, both seem works of equally mad genius.

—Thomas H. Wolf

A Guppy Swallows a Goose

It was the first recorded case of a guppy swallowing a goose—but the guppy was a Boeing 377 MG and the goose a pristinely restored Grumman G-21A. The occasion was the transportation of the Goose to the Museum for an exhibit that opened last month. The recently restored Goose is the centerpiece of "Commuting in the Modern Manner," which also features archival photographs, original timetables, and drawings.

In its day the Goose was a status symbol—the 1930s equivalent of the private railroad car. Owners of these personal airliners included such wealthy figures as Henry S. Morgan, Marshall S. Field, and Lord Beaverbrook. "Those first few were built to carry Long Island businessmen to their Manhattan offices," says senior air curator Robert C. Mikesh. "In a sense, they were the first corporate airplanes, and that is how this one will be displayed. It's painted and configured as a montage of those private commuting aircraft."

The Goose was in the middle of Grumman's famous line of seaplanes, which ranged from the cute, tiny Widgeon to the DC-3-sized Albatross. Powered by two Pratt & Whitney R-985 Wasp Jr. engines, the Goose was designed for a top speed of 200 mph and a range of about 800 miles.

The Museum's Goose was originally ordered by oilmen in Caracas, Venezuela, who requested cactus-proof tires. Eventually it ended up in California, where it was said to have once rescued Roy Rogers from a fog-bound sailboat. It found its way to Fort Lauderdale, Florida, where it was offered to the Museum.

"It was a frame and pile of parts when we got it," remembers John Lanciault from the Buehler Foundation, which donated the Goose to the Museum. After four years of painstaking restoration, one challenge remained: how to get the Goose from Fort Lauderdale to the Museum in Washington, D.C. A call went out to Erickson Air-Crane of Central Point, Oregon, which owns the Guppy. Today its chief task is ferrying Erickson's fleet of S-64E Skycrane helicopters from job to job, so aiding the Goose in its migration was a novelty. "The foundation got in touch with us and we said we'd be glad to do it," says Dale Hoke of Erickson. "It's kind of a small world when you get to this kind of outsize cargo."

Loading took eight hours. When the Goose was secured, the Guppy's four huge Pratt & Whitneys barked to life, smoking like Florida mosquito foggers and displaying their tendency to blow oil. The engines were run up and the big airplane started its takeoff roll. Seconds later it was airborne. Looking something like a blimp with wings, the corpulent silver bird climbed lazily to 10,000 feet—the cruising altitude of the unpressurized craft—and turned north to deliver the precious cargo to its new home.

—Dennis E. Powell

The Museum's new Goose prepares for its last flight aboard one of the world's few Guppies.

DENNIS E. POWELL

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

New Exhibit "Too Late for the Past, Too Early for the Future: Drawings and Things by Rowland Emett." Opens December in the Flight and the Arts gallery.

New Film Series "Time Travelers" Space Fiction Film Series: *Back to the Future,* January 5; *The Time Machine,* January 12; *Time Travelers,* January 19; *Bill & Ted's Excellent Adventure,* January 26. Langley Theater, 7:30 p.m.

December 2 Monthly Sky Lecture: "Probing the Big Bang," Douglas Duncan, Space Telescope Science Institute, Baltimore, Maryland. Einstein Planetarium, 9:30 a.m.

December 14 General Electric Aviation Lecture: "Air War in the Falklands," Group Captain Peter Squire, Royal Air Force. Langley Theater, 7:30 p.m.

December 18 Resident Associate Program Lecture: "In Pursuit of Dangerous Goals: The Amelia Earhart Story." Doris Rich, author of *Amelia Earhart, A Biography.* Hirshhorn Museum, Ring Auditorium, 8 p.m. Tickets: $7 members; $10 non-members.

January 6 Monthly Sky Lecture: "Who Owns the Stars?" David H. DeVorkin, NASM. Einstein Planetarium, 9:30 a.m.

January 17 Strategic Bombing Film Series: *Fires Were Started* (1943) and *The Battle of Britain* (1943). Langley Theater, 7:30 p.m.

January 18 General Electric Aviation Lecture: "A Piston-Powered Pilot Joins the Jet Generation," Air Vice Marshal Ron Dick, RAF (Ret.). Langley Theater, 7:30 p.m.

January 25 Wernher von Braun Memorial Lecture: To be announced. Lt. Gen. Bernard Schriever, USAF (Ret.). Langley Theater, 8 p.m.

The Battle of Los Angeles

In February 1942, Americans were furious. We'd recently been betrayed by the Pearl Harbor attack while Japanese envoys were supposed to be talking peace in Washington. We were bewildered, frustrated, and frightened, and nowhere was this truer than on the Pacific Coast. With aircraft factories, shipyards, boot camps, and air bases all just gearing up, we knew we were vulnerable and were sure that it was only a matter of time before we'd be attacked or even invaded. Thousands of men signed up to be air raid wardens in the hastily assembled civil defense organization. Many of them were military rejects like me, who'd been classified as physically unfit; others were retreads, veterans of the first world war.

The wardens from my district met regularly by the La Brea tar pits in Los Angeles to receive instructions from Army sergeants as to what we should do when the attack came. We were to stop traffic, get people inside their houses, then prepare to dig them out after their houses had been blown in. We also learned first aid.

We were issued white helmets, gas masks, and arm bands; then, along with everyone else, we waited. Newsreels of the London Blitz, with the ever-present warden, tin hat silhouetted against the flames of the burning city, gave us ideas of what to expect.

On Monday night, February 23, the war came closer to home. A Japanese submarine surfaced off Santa Barbara and lobbed shells in the general direction of some derricks and a pumping station. It was the war's first attack on the U.S. mainland; few believed it would be the last.

With an enemy sub and who knew what else out there somewhere, the city was tense. Air raid wardens met Tuesday for a last-minute review of duties, and our group sat on the grass as our sergeant delivered a cross between a locker room pep talk and a lecture. By the time we were dismissed we all looked pretty grim.

At 2:25 a.m. Wednesday the air raid sirens began their mournful, undulating wail, signaling a red alert. They yanked me out of a restless sleep to a ringing phone. It was Mr. Schultz, the Wilshire district's senior air raid warden, and he'd come completely unhinged. He kept screaming over and over, "It's a red alert! It's a red alert!" I turned on the light to get dressed, and my father growled, "What the hell kind of air raid warden are you? Turn off the goddamn lights!" Off to a shaky start.

Then all hell broke loose. From all over the city I could hear the thud of explosions. Wearing my helmet and arm band, a gas mask banging on my hip, I went into action. People were flooding into the streets to see what all the excitement was about, but I decided to worry about them after I'd stopped traffic on Olympic Boulevard.

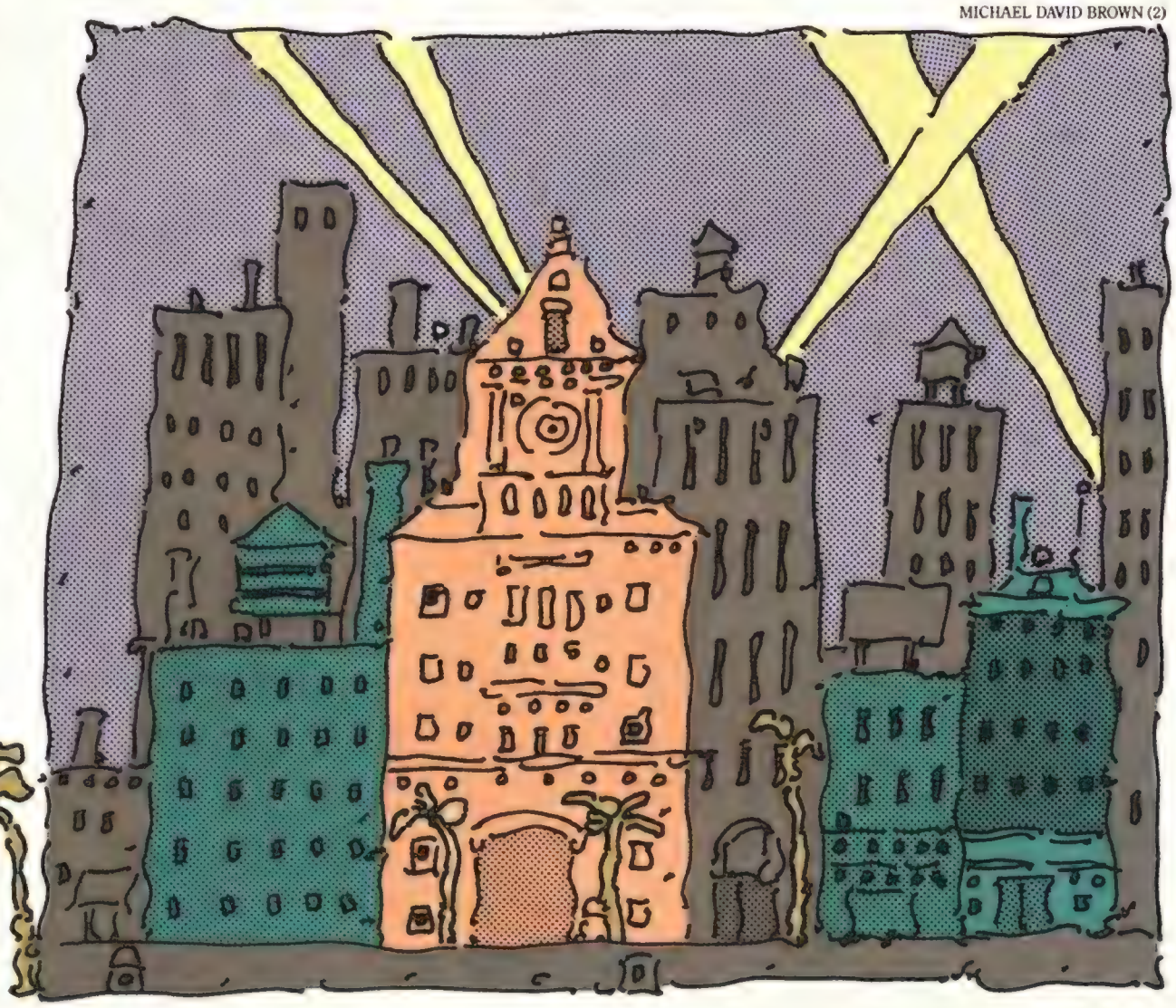
There was just one car, speeding toward me with headlights blazing. I stepped in his way and held up my hand. The driver jammed on the brakes, leaned out, and asked, "What's up?"

"We're having a red alert," I said, trying to give my voice the crisp bite of authority. "Turn off your lights, park your car, and take shelter in the nearest house." The driver made a very rude suggestion, then burned rubber as he continued west, headlights on full bright.

I thought I might have better luck getting people to take cover. As I hurried down the street I glanced upward. Searchlights met in the sky, as they did on any night in Los Angeles when they were employed for a movie premiere or the opening of a new service station.

But there was gunfire from all directions. Anyone armed with some kind of weapon—including pistols, I suspected—had let fly. There was the sharp *whang* of heavy anti-aircraft guns, then a muffled *ka-rump* as a shell burst in the general vicinity of where the searchlights were coned. Machine guns joined in; the .30s, with their rapid

MICHAEL DAVID BROWN (2)



rattatattat, and the heavier .50s, with their insistent *thump-thump-thump-thump.* Their tracers climbed into the sky in slow motion, then arced over, thousands of feet short of where the searchlight beams crossed.

People were seeing things. One man was looking up and counting, "15 . . . 19 . . . 25 . . . There's 27 of them!" I looked but couldn't see a thing, and I couldn't hear the drone of any airplanes. Not only that, the searchlights weren't moving. Whatever they were tracking had to be the slowest flying machine since Blériot had chugged across the Channel in 1909. And something else was wrong: all the pyrotechnics were in the sky. There were no explosions on the ground and none of the whistling sounds bombs made in the movies. No houses had collapsed. What kind of air raid was this, anyway?

The neighbors were determined not to miss the show. I ran from one group to another, urging them to get inside, but as soon as I'd moved on to the next bunch, the first had squirted back outside to gawk. Things weren't going at all well.

By dawn the show was beginning to wind down. Searchlights were switched off and firing was sporadic—everybody was probably running out of ammunition. The all-clear sounded at 7:21 a.m., signaling everyone to flock into the streets and compare notes. The mood was similar to the feeling that had prevailed after a series of severe earthquakes nine years earlier. The difference was that in 1933 we knew what we'd survived; that morning in 1942, we weren't so sure.

The afternoon paper was snapped up as soon as it hit the streets. Having seen so many of the great cities of the Old World subjected to bombing from the air, all of Los Angeles hungered for proof that they'd had an air raid of their own, and the *Examiner* didn't let them down: "Air Battle Rages Over Los Angeles," it proclaimed. The paper reported that at least one civilian had not only seen the airplanes but had seen three crash after being shot down.

The next day's *Times* reported that we had casualties: "Five Deaths Laid to Raid Blackout." Three people had been killed in traffic accidents, including a police officer who'd been in a head-on collision on his way to the station, a pedestrian who'd walked into the side of a moving car, and one woman who'd driven into a milk truck. Two people had died of heart attacks in the midst of the shelling, one a 36-year-old air raid warden. (Maybe Mr. Schultz had called him too.) There'd also been countless injuries in street accidents. With cars and trucks bumping into one another and running over wandering pedestrians, it was apparent that other beleaguered air raid wardens hadn't been any more successful in carrying out their tasks than I'd been.

By then the Army and Navy were bogged down in controversy. Navy secretary Frank Knox had started it all when he suggested the Los Angeles alert had been a false alarm, probably due to "jittery nerves."

That did it. "Army Says Alarm Real," the *Times* declared. "Overshadowing a nationwide maelstrom of rumors and conflicting reports, the Army's Western Defense Command yesterday insisted that Los Angeles' early morning blackout and anti-aircraft action were the result of unidentified aircraft sighted over the beach area."

By Friday morning, everybody had pretty much calmed down—everybody except the Army and the Navy, which were still squabbling. The Navy kept insisting the whole thing had been a false alarm. The Army, determined that no one should get the idea they'd panicked and unlimbered anything that even looked like it could shoot, now raised the ante. "Stimson Says 15 Planes Over City," the *Times* reported. Secretary of War Henry L. Stimson was quoted suggesting a scenario that even then seemed improbable: " . . . the unidentified craft may have been commercial planes flown by enemy agents to spread alarm, disclose anti-aircraft gun positions and test the effectiveness of blackouts." He consoled the enthusiastic artillery brigade by adding, "Perhaps it is better to be too alert than not alert enough."

What really happened in the skies over Los Angeles that February morning? Twenty-two years later the jury was still out. The military history series *U.S. Army in World War II—The Western Hemisphere,* published in 1964, reports on what became known as The Battle of Los Angeles: "About two o'clock in the morning a series of reports of suspicious activities was capped by word that coastal radars had picked up an unidentified plane winging its way in from the ocean toward Los Angeles . . . a blackout was ordered and all antiaircraft guns were alerted for instant fire. The guns began to fire shortly after three o'clock, the first shot being aimed at a balloon (probably a meteorological balloon) over Santa Monica on the coast. During the next hour they expended some 1,400 rounds of 3-inch antiaircraft ammunition against a variety of 'targets' . . . . Exhaustive inquiries . . . accumulated a mass of conflicting evidence as to what those targets were. The Army finally concluded that there had been from one to five unidentified planes that had touched off the 'battle' whereas the Navy decided there had been no excuse for the firing. It is at least possible that the I-17 [Japanese submarine] launched the plane it carried to spark the confusion, although it is very unlikely this plane flew inland over the coast line."

With words like "targets" and "battle" in quotes, I get the feeling the Army historians were having trouble taking the episode seriously. But their description seems probable, and a little reading between the lines adds more color.

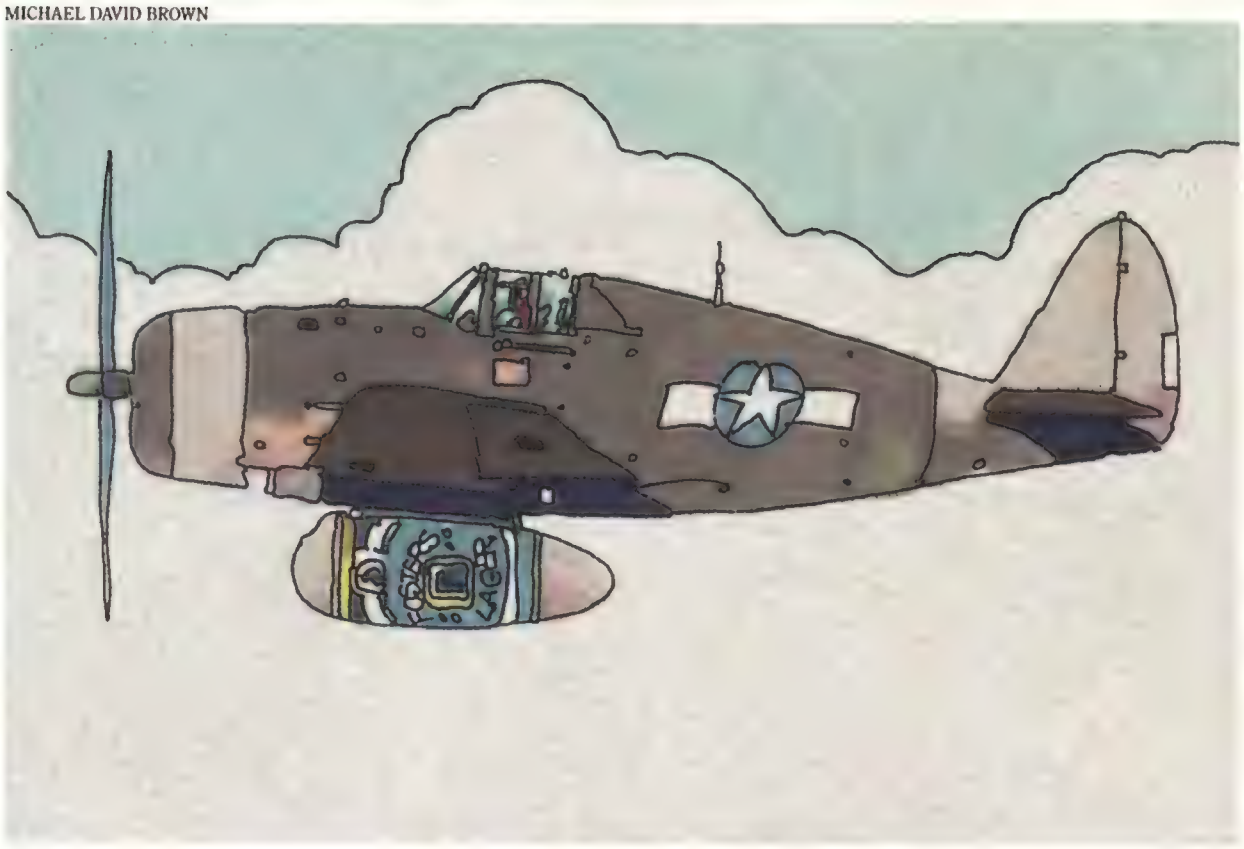
The I-17 was big enough to carry a floatplane, which was stowed in sections and had to be put together every time it went up. The temptation to send the airplane over all the bright lights along the coast, even if only to go sightseeing, may well have been irresistible, and such a flight would have also dramatically demonstrated that the Japanese could, indeed, go wherever they damn well pleased.

If the I-17's airplane had flown over Los Angeles, or even come close to the coastline, it's doubtful that it lingered. After running into the pent-up anger, frustration, and anxiety of people given their first opportunity to fight back, the pilot probably executed a smart 180, firewalled that sucker, and scuttled back to the sub, where the crew would have taken the airplane apart, stowed it, and gotten the hell out of there. Hasty retreat notwithstanding, the pilot would have succeeded splendidly in spreading alarm and learning in record time the location of every firearm in Los Angeles. He'd also have revealed that the city's civil defense program needed a little work.

—Tom Swafford

The Big Chiller

MICHAEL DAVID BROWN



Wartime memories long kept me from making decent peacetime landings. The Republic P-47D I'd flown in New Guinea had weighed about seven tons, and though it was held up by Pratt & Whitney and God, its dearest wish was to return to earth. After a long, buttock-cramping mission, you were grimy, you smelled bad, and you were exhausted. The strip came up at you, and you just kept the big beast flying with the throttle until you crossed the end of it. Forget about a gentle flare for a wheel-chirping landing. You just chopped the throttle and brought the stick back to your sweaty belly, and with a satisfying *kerflump,* all that heavy metal slumped onto the steel matting. Home at last!

Then came the beer flights. Our P-47s were getting creaky, so a contingent of pilots ferried them about 1,500 miles to Brisbane, Australia, swapped them for new craft, and flew those back to our island. They also brought many welcome bottles of wonderful Australian beer: Foster's, Tooheys, Victoria Bitter—dark and strong, bought with squadron funds and shipped in our colleagues' parachute bags, padded in dirty laundry.

The beer was a marvelous morale builder, but in the pre-icemaker era the tropics rendered it too warm for civilized tastes. "Come on over and have a hot beer" was the standard invitation.

One day one of the new airplanes had just had an engine job that needed to be broken in—"slow-timed," we called it. A guy with a name like Riley volunteered. Remembering something he'd been told by a more experienced P-47 pilot, Riley got the armament officer to help him open the wing slot where the cartridge belt for one of the guns was stored. They took out the heavy box of .50s and inserted a bottle of hot beer. Wing slot temperature was the same as outside temperature, which even in the tropics was below freezing if you got high enough. Riley climbed to 20,000 feet and flew around awhile; when he landed, the beer was beautifully chilled. We reluctantly agreed that he and the armament officer deserved most of it.

From then on, two or three P-47s were always humming serenely far above our camp, their cartridge boxes innocent of anything more lethal than chilling beer. We crossed our fingers that no Japanese Oscars would show up, though the possibilities fascinated us: rattling machine guns, tinkling glass, evasive action marked by a plume of suds.

Fortunately, the Japanese missed their chance. The only peril facing the beer coolers was landing. As operations officer, I and the commanding officer would arrive at the end of the airstrip with a flare gun when a landing was imminent. Whenever a P-47, wings sagging with frosted bottles, looked as though it was about to make the standard *kerflump* landing, I'd fire a red flare and send it around.

"Just paint it on, main wheels first," the CO would say. "I don't want to hear a sound when you touch. Don't even rattle the matting."

We both flew some cooling flights ourselves—not too high or the beer would freeze and crack the glass, not too low or the bottles wouldn't get a lasting chill. And the landings! We'd drag our airplanes in like DC-3s, keeping the tail up, easing the main wheels to the runway—and like as not, getting a flare from the assistant operations officer, who seemed to love firing that pistol at us. We soon learned to land a little past the usual spot on the steel matting so we could avoid a distinct dent where, mission after mission, weary pilots had *kerflump*ed.

After the war, when I first tried to fly a feather-light civilian airplane, my P-47-type landings rendered my instructor nearly speechless. "Your airspeed's 75!" he choked out on my first approach to the runway. *Good grief,* I thought, *only 75?* I gave the Luscombe more throttle, and we sped down the runway, daintily touching a wheel now and then.

When I mastered slower speeds, I faced the problem of dropping in. "You're going to drop it in!" the instructor would gasp as I came over the approach end of the runway at the height of a P-47 cockpit. "Natch," I would murmur, then—*kerflump.*

The only way I could make myself set the little butterfly down properly was to pretend that my wings were bulging with those big brown bottles from Brisbane.

—*Edwards Park*

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Flying at the Bottom of the World

Rule no. 1 for travelers in Antarctica: If there's a flight available, take it.

by Charlotte Evans *Photographs by Ann Hawthorne*

Williams Field, the airport that serves Antarctica's McMurdo Station, is no ordinary airstrip. Constructed of packed snow, it sits atop the hundred-foot-thick Ross Ice Shelf, which, due to glacial pressure, is continually moving north and losing chunks of itself to the sea. Willy Field, as it's known locally, has to be moved every five years or so to keep it from following suit. Fortunately, many of its buildings are mounted on skis, as are all the airplanes that use it.

A second landing strip is reconstituted every year on a section of frozen ocean near McMurdo. Eight to 20 feet thick, it can accommodate wheeled aircraft, but only from the beginning of the summer season in early October until the middle of December. After that it turns slushy, and by the end of January it often breaks up and moves out to sea.

In Antarctica, moving airstrips are to be expected. Ice, some of it more than two miles thick, covers 97 percent of the continent's surface. The coldest temperature recorded on this planet—nearly 127 degrees below zero—was chalked up in Antarctica, where winter winds often howl at speeds of 100 mph. It is an environment that is, at best, indifferent to human needs. In extreme cold, even small tasks like pulling on tube socks consume undue energy. Because supplies and manpower are limited, teamwork and ingenuity are mandatory, whether the task is fashioning a Halloween costume from styrofoam and bubble wrap, concocting pesto sauce in a tent from dried basil and Wesson oil, or persuading a penguin to accept fish from human hands as part of a metabolism study.

Under these extreme conditions, aviation has become a valuable research tool for the National Science Foundation, which runs the U.S. mission in Antarctica. Thanks to the seven LC-130 Hercules cargo planes and six UH-1N Huey helicopters of "the world's southernmost airline," the United States car-

Snowmobiles are fine, but if you want to go a long way fast in Antarctica you can't beat the LC-130 Hercules.

ries out the biggest and most sophisticated scientific research program on the icy continent.

The four-engine Hercs can move people, equipment, and supplies with a speed and flexibility far beyond what ships could provide. During the peak of the summer season they make the 2,200-mile trip between McMurdo and the U.S. Antarctic program base in Christchurch, New Zealand, about three times a week. On the ice itself the helicopters service camps close to McMurdo. The Hercs, equipped with Teflon-coated skis, can place science parties in remote field camps or ferry them within hours from McMurdo to inland stations such as the South Pole.

"It's terrifically productive and no one else does it," says Guy G. Guthridge, a spokesman for the NSF, the organization that represents the United States in Antarctica. (Under the Antarctic Treaty, now signed by 17 nations, the continent is reserved for peaceful, nonpolitical research.) The NSF's most ambitious project last season, consuming 419 Hercules hours, was the Siple Coast glaciology program, in which nine scientists investigated ice streams to determine changes since the glacial age and the glaciers' response to and impact on global climate.

Airplanes have served in Antarctica since 1929, when both Sir Hubert Wilkins and Admiral Richard Byrd brought them along on their expeditions. Wilkins had two Lockheed Vegas; Byrd, who had made the first flight over the North Pole three years earlier, brought three airplanes. One was destroyed when fierce winds hurled it half a mile during a storm. He used another, a Ford Trimotor named *Floyd Bennett* after his North Pole pilot, to make the first flight over the South Pole later that year.

In 1935 explorer Lincoln Ellsworth and pilot Herbert Hollick-Kenyon made the first transantarctic flight, a 2,400-mile odyssey from Dundee Island to Byrd's campsite at Little America. It took 22 days. After bad weather trapped them on the ground for more than a week, Ellsworth and Hollick-Kenyon found that the blizzard had packed their Northrop Gamma full of snow. It took them a full day to empty it—using only a teacup. The last 25 miles of the trip, made on foot because the men had run out of fuel, took six arduous days.

Weather is unpredictable at best. When visibility is low, balloons are used to measure the cloud ceiling.

In the years since, Antarctic flying has expanded dramatically despite the often severe conditions. During the 1988-89 season, Herc crews logged approximately 3,400 flight hours; helo crews, 1,200. The helicopters transported 65 scientific teams, both U.S. and New Zealand, to inland stations or field camps: the Hercs alone hauled 3,798,183 pounds of cargo and 112,530 pounds of mail. Apart from the science effort, the wide-ranging Hercules also give the United States the only long-distance search-and-rescue capability on the continent.

Recently the tables were turned when a Hercules became the object of a rescue mission. The airplane, known as 321, had crashed in 1971 during a resupply mission. It had been taking off from the ice 750 miles northwest of McMurdo when a JATO (jet-assisted take-off) bottle exploded and sent fragments into an engine. No one was injured but the airplane was declared a total loss and stripped for parts. Over the years it had become buried in ice. But after conducting feasibility studies in the mid-'80s, the NSF decided that spending $7 million to recover the airplane was a better deal than shelling out $35 million for a new one.

Recovering the 97-foot-long Hercules proved to be, well, Herculean. By the summer season of 1986-1987 the only portion of the airplane visible above the snow and ice was a three-foot section of its tail. A seven-man crew flew out to D'umont d'Urville, a French camp about 115 nautical miles from the Hercules, moved a bulldozer across the snow and ice to the site, established a camp, and forged a skiway. Using bulldozers, then shovels, the crew worked six weeks to free the airplane.

Over the next winter, with the operation suspended for the season, snow had drifted as high as 15 feet over the airplane's skis, and a crew from the Naval Aviation Rework Facility at Cherry Point, North Carolina, had to dig it out again. After working for 42 days in numbing cold, they had to replace all four engines and propellers and make structural and electrical repairs. Engineers from Lockheed and the Navy then deemed the craft airworthy.

On January 10, 1988, pilot Kent White and his commander, Jack Rector, flew out from Williams Field in another Hercules. They were on their way to the crash site to fly the recovered airplane back to McMurdo for its return to active duty. Their task was made more compelling by the presence of another Herc at the crash site. It lay in pieces at the end of the 8,000-foot ice runway, where it had crashed a month earlier when it stalled on approach while bringing in parts for 321. Two members of the Navy's Antarctic Development Squadron 6, or VXE-6, were killed and nine were injured. Before the crash it was assumed that the restoration of 321 would increase the fleet to eight. Now it was a matter of breaking even at seven.

Arriving at the site, White and Rector confronted a potentially crippling glitch. The starter on 321's no. 4 engine was leaking oil and had to be removed. Without a starter the engine would require help from the working Hercules. Parked on the skiway in front of 321, the men turned up their airplane's engines, hoping its prop wash would activate engine no. 4 the way an electric fan would start

U.S. NAVY

Equipped with the largest skis ever installed on an airplane, the LC-130 can also operate on wheels.

After years on ice, this Hercules was dug out and resuscitated. It will soon be back on active duty.

a pinwheel. Slowly, almost imperceptibly at first, the propeller began to turn, then became a blur. Soon 321 was airborne. After being refurbished in the States, the airplane will eventually travel back south to rejoin the fleet.

Rector called the flyout the "glamour part" of the project. The hard part would be more routine: moving all the equipment necessary for the recovery out of the camp.

There are are no shopping malls, restaurants, cars, pets, children, or senior citizens at McMurdo Station. There is little privacy: just about every-

body has a roommate, and because of the danger of storms, it is against the rules to leave town alone. When the weather is bad, the dorms are filled with grouchy, field-eager scientists, eyes glazed over from watching the same videos over and over again.

The Herc crews are exceptions in the Antarctic community because they get out regularly on trips to New Zealand. When they return they often bring a few treasures back to the ice—a bottle of real milk (McMurdo carries only the powdered variety), a box of fresh strawberries, a surprise birthday bouquet of long-stemmed roses.

The helo crews have more opportunities to interact with passengers as they visit field camps to deliver supplies, equipment, mail, and gossip. A favorite stop is New Zealand's Vanda Station in the Dry Valleys, where you can get freshly baked scones and steaming tea or chocolate.

"Routine" is a word that characterizes much Antarctic flying today. The year's flight schedule is established in Washington before the season opens. Twice a week officials of the NSF, which owns the airplanes, and VXE-6, which actually flies them, meet to discuss any modifications of the schedule. "We really march to their drumbeat," says Commander Jack Smith, a helicopter pilot who led the squadron during the 1988-1989 season. "If they want us to do A instead of C, that's fine, so long as we can do it safely and not exceed our limits."

The schedule can be punishing. "We fly almost a year's [normal] flight time in five months," says Smith, "around the clock and six days a week for the entire four-and-a-half-month period, really keeping people right on the edge of their capability and capacity."

But it's nature that ultimately rules the icy desert, and weather and maintenance problems often mangle schedules. You don't need to say "weather permitting" when planning to launch an ozone sonde, collect rock samples, drill a dive hole, schedule a flight, or even accept a dinner invitation. Weather forecasting in Antarctica is "chancy at best," according to Terry Cooke, a Navy meteorologist. "You've got a continent the size of the United States and Mexico with basically only 12 reports coming in every six hours," he says. "Most pilots understand what we're going through and respect us for doing it." Sometimes, however, they "come into the weather office and bitch that they had to turn around on the spur of the moment and 'it's all because of you.' "

Robert F. Scott perished in Antarctica in 1912; his camp remains, preserved by the frigid, dry climate.

Despite the efforts of forecasters, blue sky and white surface can turn into white-out conditions without warning. Pilots call it "nil and nil," meaning they have no horizon and no surface definition. "It's like flying in a big bowl of milk," says pilot Kay Griffiths-Rossi.

"You're staring at the same color," says pilot Frank Mendicino. "The horizon gives you your reference. When it goes away your middle ear can play tricks on you and you're not sure what your attitude is. Am I turning or straight? Am I diving or climbing?"

If you do get into trouble, getting out isn't so easy. "In California, if you go off the runway you can still go home at night, or maybe to a hospital," says Scott Lyons, another Hercules pilot. "In Antarctica you're in an extreme survival situation."

Antarctica's worst air disaster occurred in 1979, when an Air New Zealand jet on a sightseeing trip flew into the side of Mt. Erebus, killing all 257 aboard. In U.S. government programs, 50 people have died since 1946. Nine aircraft accidents, all before 1970, caused 30 of the deaths. Then, in 1987, VXE-6 lost four men in the crash of a helicopter on a training mission in the mountains near the squadron's home base of Point Mugu, California. The two deaths from the 1987 recovery operation numbed the McMurdo community and forced everybody to once again ponder the commanding presence of nature and the wisdom of flying in its face.

Dave Coggan, the navigator, survived the crash with cracked cartilage and a sprained ankle. "I felt the aircraft shudder," he says. "I opened my eyes and everything was quiet and cold and the copilot was in the seat hanging above me. The first thing I really noticed was the silence. The next thing was how cold my hands were. The windows were broken and snow was blowing through the cockpit. The first thing I tried to do was to check out my own condition. *OK, let's see if my legs work.* I moved my feet and they moved. I checked my hands and arms. They were all there. I felt my face and checked my teeth with my tongue."

Coggan says he never hesitated getting back on an airplane, but others had difficulty. It was months before John Jaenisch, the flight engineer, flew again. "Everybody goes through this thing, 'It can't happen to me,' " he says. "Then you realize that it did. Nobody's invinci-

ble. Basically it can happen to you."

One crash survivor left the Navy. Others sought help from Tim Sims, the squadron chaplain, and Leland Mills, the flight surgeon. "They start to question themselves," says Mills. "Is it worth it? Is it that much fun? After a while they come to an answer that is right for them—yeah, there is a risk. It is dangerous. It's also a thrill; it's rewarding, satisfying, goal-oriented."

Frank Mendicino remembers the risk every time he gets dressed. Along with his dogtags he wears a metal fragment from a Herc that crashed at the South Pole. "It reminds me of what I'm doing," he says. "I don't want to be overwhelmed with thoughts of crashing, but I don't want to be complacent."

Safe flying in Antarctica requires dedication to procedure. "Where there's an emergency there's no time to pick the book up," says Billy Keeler, the command master chief. Antarctica being what it is, however, procedure doesn't always work.

Helicopters are ideal for supplying sites near McMurdo. Two Hueys carry a meteorite survey party to a camp (left). In Victoria Valley, geologist Mike Malim receives a visit from a helicopter crew (above).

In January 1988 Kent White, piloting a mission to recover a payload launched by balloon to study supernova 1987A, planned to land on the polar plateau about 180 miles southwest of the Soviet Union's Vostok Station. The normal procedure for landing at a remote site calls for the pilot to test the surface with a ski drag. He approaches the ground as if to land, but first merely drags the main skis along the surface to test for snow-covered crevasses. He ascends again and circles to study the surface. He then makes a second approach, about 200 yards parallel to the first, and drags the skis once more. If the surface appears safe, he lands in between the ski marks. Routine.

The reconnaissance airplane that had located the payload reported that the edges of the *sastruggi,* or snow waves, were well defined, indicating hard-packed snow suitable for a landing. The crew's worry was that the airplane

There's fun to be had before the annual "Penguin Bowl," which pits squadron against civilians.

Located on the edge of the Ross Ice Shelf, McMurdo Station provides access to inland Antarctica.

would be severely battered by the hard ridges. Instead, as the skis hit the ground for the first drag they sank into a foot and a half of powder that grabbed the airplane like quicksand. "All of a sudden we were on the ground," says William Lamar, the flight engineer. "It was all unintentional. Kent White says: 'How did this happen?' Here we are, way out in the middle of no place, set up for a normal procedure. All of a sudden it doesn't work as advertised. You start thinking about a lot of things, like about getting into a survival situation and having to set up camp."

The scientists aboard had been promised two hours on the ground, but White cut their time in half: he would have to keep the engines running and wanted to conserve fuel for a takeoff he knew would be made difficult by the deep powder. Four of the nine crew members remained in their seats, on oxygen since they were above 10,000 feet; the others helped drag in the payload.

Once it was secured, the passengers were strapped into the rear of the airplane—all the way up the loading ramp—with a cargo belt. White wanted to get as much weight as possible in the back to help the airplane's nose lift off from the powdery snow. Then they started taxiing. Eight miles later they were still taxiing. What would happen,


COAST GUARD

In a land where humans are still a relative oddity, penguins remain approachable.

Its shadow haloed against the clouds, a Hercules approaches Mt. Erebus, site of the continent's worst air disaster.

people started to wonder, if they couldn't take off?

There was talk of taxiing the 100 miles to Vostok, a long trip at 10 to 15 miles an hour. Someone mentioned the leather outerwear and fur hats worn by the Soviets and what the Americans might have to trade for some. Somebody else replied that it was too bad they didn't have any Coca-Cola or *Penthouse* magazines. Another joked that they could probably trade crew member Kay Griffiths-Rossi.

The talk turned serious. They discussed setting up camp and whether McMurdo would risk sending an airplane with fuel for another takeoff attempt. White decided to turn the aircraft around and begin taxiing over the packed snow of the first run. Eight miles later the Hercules lifted off, leaving its passengers feeling both relieved and oddly disappointed.

Despite such trials, Antarctica, like an aloof lover, is difficult to resist. It is a place beyond mundane obligations. "There is a certain purity that I derive from being down there, away from all the distractions of civilization—no bills, no driving a car," says Scott Lyons. "Some of the friendships I have made here are among the best in my life."

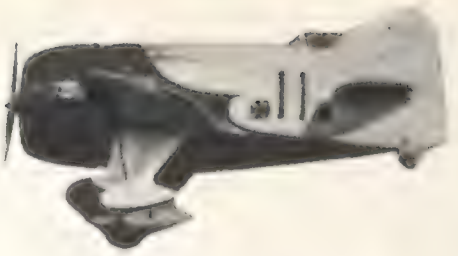
It also offers unparalleled adventure and the lure of unspoiled nature—a chance to sleep in an igloo, photograph Emperor penguins, or collect wind-sculpted rocks. When the wind isn't blowing it's possible to hear no sound but your heartbeat. Hector Rodriguez, a helicopter crew chief, recalls eating lunch in a helicopter that was parked on the ice edge when "a baby whale just jumped out of the water—straight up and back in."

Flight engineer William Lamar, now in the middle of his 10th season in Antarctica, remembers one of the first times he landed at a remote site. "I walked away from the plane and just looked at the vastness," he says. "I'm not religious, but I marvel at the creation. Somebody bigger than all of us had to do something like this. This is definitely not man-made."

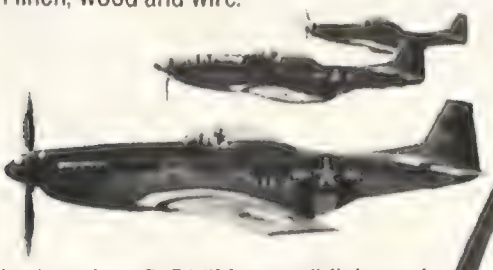
CAPTAIN PAUL DEROCHER, USN

In 1903, the Wright Brothers first flew a powered aircraft—for 90 yards—a flimsy plane of linen, wood and wire.

The legendary "Red Baron"—80 kills in World War I made his red Fokker triplane the scourge of the skies.

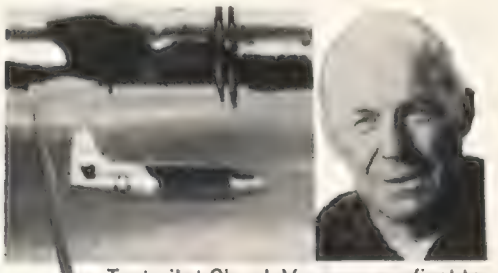


In 1932, Jimmy Doolittle set a world record of over 300 mph. in a GeeBee—a speed machine "nearly all engine" and very dangerous to fly.



The American P-51 "Mustang" fighter of World War II fame, provided strong bomber escort protection with its 2,300-mile range.

FASTER HIGHER FARTHER



Test pilot Chuck Yeager was first to fly faster than the speed of sound. In 1947, his bullet-shaped Bell X-1 reached 700 mph —later Mach 2.5.

The SR-71 "Blackbird" can sustain a speed of over Mach 3 on the very edge of space.

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Goodbye, Voyager

Photographs by Roger Ressmeyer/Starlight

After 12 years of rewriting the textbooks, Voyager 2 has met its last planet. But its journey is just beginning.

by Mark Washburn

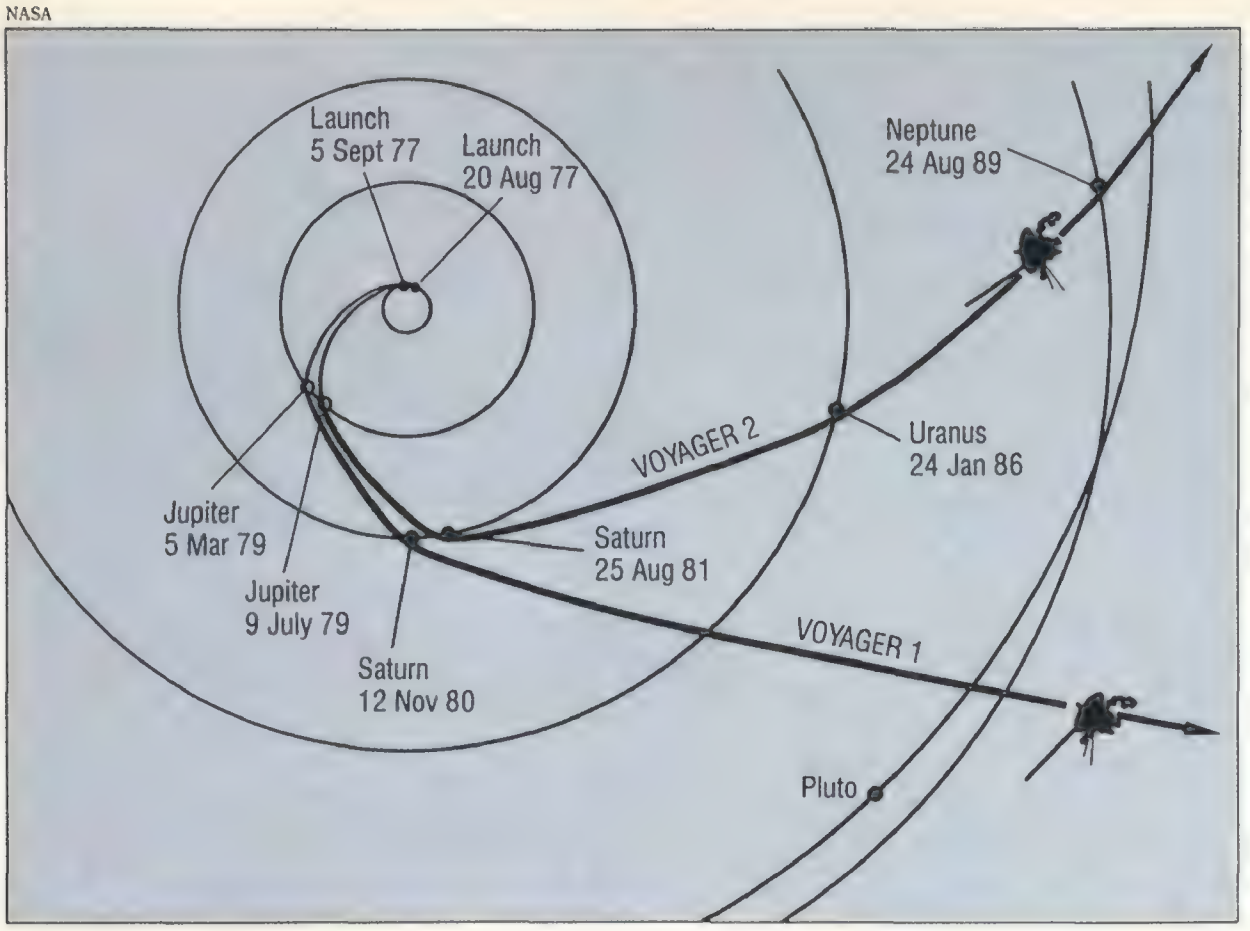
The road to the stars begins at the end of Oak Grove Drive, just northwest of Pasadena, beyond a high school, a riding academy, and the world's first Frisbee golf course. Here, at the head of a dry arroyo nestled against the San Gabriel Mountains, the Jet Propulsion Laboratory, home of America's planetary exploration program, stands like a small frontier community on the rim of a vast, untracked wilderness.

I returned to JPL on August 20, 1989, twelve years to the day after the launch of the Voyager 2 spacecraft. Six times since that launch I had journeyed across the continent

Voyager 2's spectacular Neptune images arrived at JPL after a 2.8 billion-mile, four-hour trip. This false-color image of the planet shows details of the cloud structure. Pinkish clouds are higher than the darker ones.

VOYAGER PHOTOS PROVIDED BY JPL

NASA



The Voyagers' itinerary was made possible by a planetary alignment that occurs only once every 176 years.

to chronicle the progress of the robot explorer and its twin, Voyager 1. A former history teacher, I had always been fascinated by the grand explorations of bygone centuries—What must it have been like to sail with Columbus or cross the mountains with Lewis and Clark? Quite unexpectedly, I had the opportunity to find out firsthand. The Viking mission to Mars in 1976 introduced me to the joys of planetary exploration. But Viking saw just one planet; Voyager was to see four. There were two Jupiter flybys in 1979, Saturn encounters in 1980 and 1981, and a single swoop past Uranus in 1986. Now, a curving trajectory had carried Voyager 2 some 2.8 billion miles from the fires of the sun, to the remotest outpost of the solar system: the planet Neptune.

I was drawn to JPL this time by more than just scientific curiosity and the thrill of exploration. This was to be Voyager's final planetary encounter. Afterwards, scientists would return to their offices and laboratories throughout the world and try to make sense of what they had learned. But that would be work for solitary thinkers and small groups of analysts. Never again would the Voyager community gather to share the experience of seeing an unknown world for the first time. For those of us who had spent the best years of our lives following Voyager, Neptune was to be the last dance—one last cosmic tango, cheek to cheek with the Great Unknown.

"I think that Voyager is truly unique," says astronomer David Morrison of the Ames Research Center. "It obviously is, in the simple factual sense of being the first spacecraft to go to these other worlds, but I think it is also unique in the kinds of bonds it has forged over this long time period, between people who are pioneers—the closeness you have between the scientists and engineers, the operations people, the press. I really don't think that this will happen again. Perhaps something better will come along. Maybe I'm just being an old fogey, but I feel as though this is really the passing of a very special thing."

Voyager has handed atmospheric theorist Andrew Ingersoll as many questions as answers.

The sense of impending loss made the Neptune encounter a poignant experience. The JPL press center in the Von Karman auditorium was like a village green, a gathering place where news and gossip were exchanged, friendships renewed, the past remembered, and the future anticipated. I felt as if I were back in the small town where I grew up.

At the opening press conference on August 21, Edward Stone, the project scientist since Voyager's inception in 1972, described the coming Neptune flyby as "the final movement of the Voyager symphony of the outer planets." After the crashing cymbals of Jupiter, the baroque fugue of Saturn, and the haunting, atonal Uranus passage, no one knew what to expect from Neptune, but experience had taught us to expect the unexpected.

The entire Neptune encounter was, in a sense, unexpected. A poor stepchild of a canceled "Grand Tour" mission to the outer planets, Voyager was conceived when NASA's budgets were declining in the wake of the Apollo moon missions and most of the agency's remaining money was targeted for the space shuttle. Voyager was to be an economical five-year excursion to Jupiter and Saturn. But mission planners realized that the spacecraft could still follow the trajectories envisioned for the Grand Tour and use the gravitational energy of each planet to swing them onward to the next. If the spacecraft survived, there was no reason why Voyager 2 could not continue onward to Uranus and Neptune.

Survival, however, was far from certain. From the very hour of its launch Voyager 2 had been plagued by troublesome glitches that taxed the capabilities of the spacecraft and the people who controlled it. By the end of the 1981 Saturn encounter, the spacecraft was showing its age and budget-cutters in

Jupiter

Both Voyagers whizzed by Jupiter in 1979. They sent back stunning photos of the gas giant as well as its four Galilean moons, shown here in a composite image.

Washington were trying to pull the plug on the mission. But Voyager 2 defied the odds and arrived safely at Uranus in 1986. Three and a half years later, it was about to complete the Grand Tour.

At the time of the Voyager encounter Neptune was the planet most distant from the sun (Pluto's eccentric orbit temporarily brings it closer). Even traveling at the speed of light, commands from Earth took four hours to reach the spacecraft; in practice, command sequences had to be planned and "uplinked" days in advance. Voyager scientists were forced to plan their observations knowing relatively little about their distant target.

In the 143 years since the discovery of Neptune, Earth-based observations had established that the planet is big, blue, cold, and composed mainly of hydrogen gas—like Jupiter, Saturn, and Uranus, Neptune has nothing resembling a solid surface. Scientists knew it had at least two moons, one of which, Triton, possessed a thin atmosphere. They also knew that Neptune had a set of rings which, as seen from Earth, seemed to be incomplete "ring arcs." Aside from these bare-bones facts, little else was known. As Voyager imaging team leader Bradford Smith put it, "Everything that we've seen is new."

By now, Smith, a University of Arizona astronomer, and his team were accustomed to seeing their pet theories about the planets knocked down by the onslaught of new facts. Early in the mission the scientists had held their cards close to their vests, protecting themselves and their theories from a press corps that didn't understand the scientific process. But as the planets rolled by and stunning new discoveries became the accepted norm, the scientists loosened up and the press actually became protective of their subjects. It was rather like the relationship between a group of primatologists and the mountain gorillas they observe. Ten years of graded exposure had produced a mutual trust and understanding, and at times it was unclear who was observing whom.

Brad Smith's attitude toward the press seemed to evolve from wary tolerance to amused fascination. Where once he had announced new discoveries in a laconic monotone, now he laced his delivery with jokes, personal reactions, and hand gestures that some were convinced he made simply to get a rise out of the photographers.

Neptune provided Smith and the press corps with first-rate material. While Earth's atmospheric circulation system is powered by energy from the sun, sunlight is dim and weak in the outer solar system. Nevertheless, Neptune was turning out to be a world of churning activity and unexpected energy. For months, Voyager's cameras had been sending back images of a beautiful blue ball speckled with fleecy white cirrus clouds that were startlingly evocative of Earth. The planet was dominated by an immense oval feature that the imaging team had dubbed the Great Dark Spot because of its resemblance, in all aspects but color, to the famed Great Red Spot of Jupiter. By tracking the motion of the GDS and other atmospheric features, the scientists hoped to establish the planet's rotational period and atmospheric circulation patterns.

The Saturn encounters revolutionized knowledge of ring systems. Once Saturn was thought to possess only three rings; the Voyagers revealed a much more complex structure.

That task fell primarily to a group headed by Andrew Ingersoll, an atmospheric theorist at the California Institute of Technology who had joined the mission team relatively late, just shortly before Voyager's 1977 launch. Says Ingersoll, "I'm extremely glad that Brad Smith asked me to join the Voyager team because even if your ultimate goal is to build theoretical models, you have to be involved in the collection of the data. I didn't realize how much fun it would be."

Because it saw only the cloudtops of the four outer planets, Voyager generated more questions than answers. Ingersoll would like to understand the mechanisms that energize the flowing, swirling clouds glimpsed by Voyager, and find out what lies beneath them. If he had five minutes with God, Ingersoll says, he has a question he would ask: "How deep does it go?"

For Ingersoll, all four outer planets have been something of a surprise. "I would have thought that they'd be much duller," he says. "Even a year ago, I thought Neptune was going to be much duller than it was . . . . Voyager will surprise you, the planets will surprise you. It's fun to sit back and be surprised."

The encounter was fun for all concerned, but it was also hard work. On the morning of the 24th, the day of the closest approach to Neptune and Triton, Ed Stone told the press, "Well, this is the the day. I hope you've all figured out when you're going to sleep. I haven't." Voyager would cross the plane of Neptune's rings around midnight—the moment of maximum peril for the spacecraft, which could be smashed to pieces if the ring particles turned out to be bigger or more numerous than expected. Then, at about 3:30 a.m. on the 25th, the highest-resolution images of Triton would arrive on the ground, an event that was likely to be the high point of the encounter. As we had during the previous all-nighters at other planetary encounters, we would depend on coffee and adrenaline to keep us going.

The staff of the public information office in Von Karman supplied the coffee; Triton and Voyager supplied the adrenaline. "We have people literally jumping up and down," Brad Smith said of his imaging team that night. Even from a distance, Triton was beginning to look wonderfully weird.

But before Voyager could get there it would have to survive the inbound ring plane crossing. If the spacecraft met with disaster—as it almost did at Saturn when it actually passed through a ring—the signals from Neptune would simply stop. As the moment approached for the arrival of the data, scientists and journalists throughout the lab dropped what they were doing and waited anxiously. Data from one of Voyager's instruments began to show a huge increase in the number of "hits" by microscopic particles crashing into the spacecraft.

The count peaked, then slowly began to decline, and the signals continued to arrive. The imaging team uncorked a bottle of champagne.

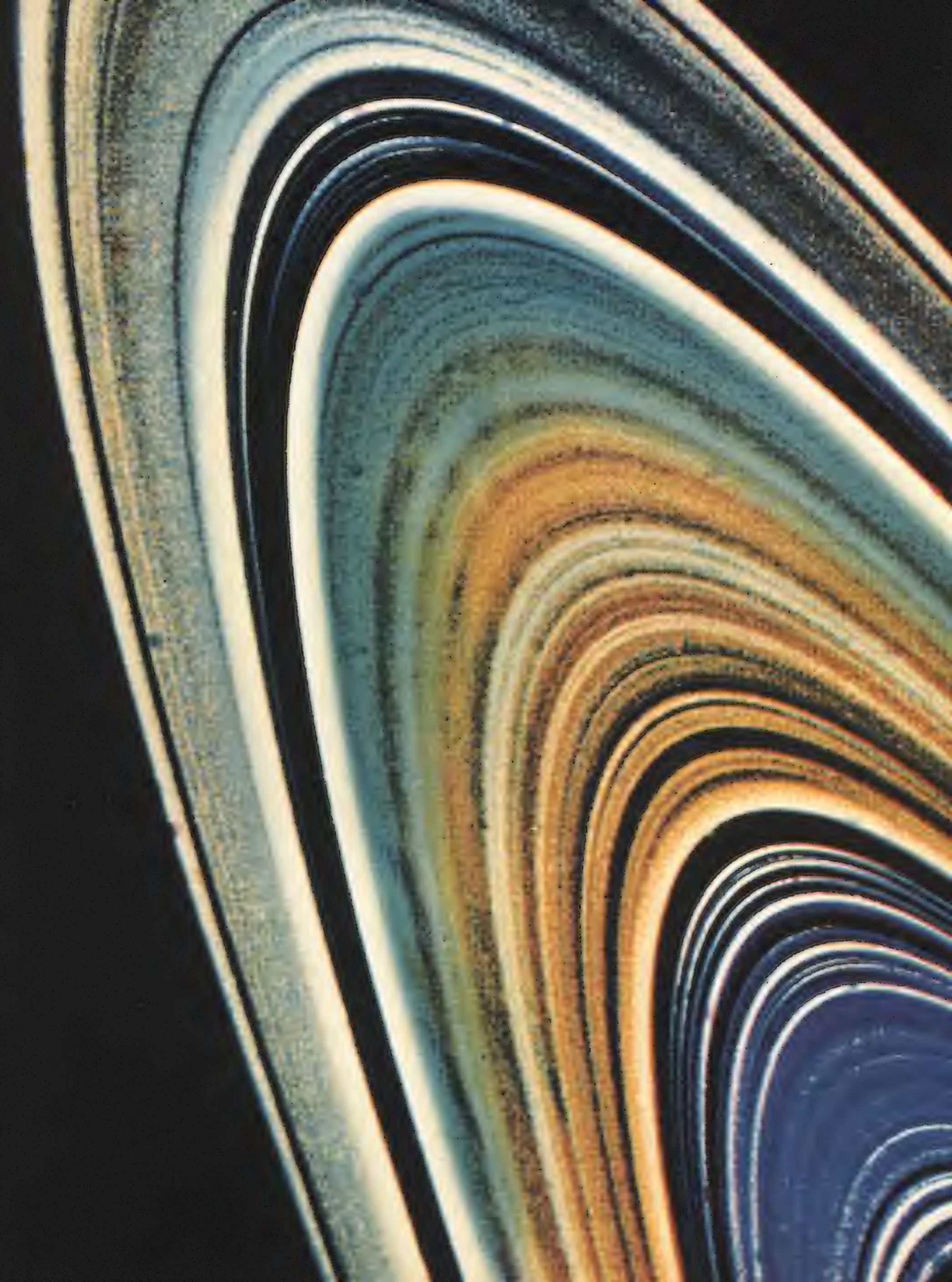
"Made it!" I whooped when I saw Stone a couple of minutes later. "Made it!" he responded, punching the air with his fist. "Again!" I added. "Again!" he echoed ecstatically. I had never seen him look so happy.

And why not? For 17 long years, Voyager had been his baby. He had helped recruit the science teams, design the encounter sequences, and accommodate the often conflicting desires of astronomers, geologists, physicists, engineers, and NASA managers. His expertise, patience, and unflagging good nature had been one of the wonders of the mission. Like his spacecraft, Stone had endured and prevailed despite astonishing pressure. Now, finally, there was nothing left to go wrong. Voyager had survived its perilous journey.

Three hours later, the high-resolution images of Triton arrived. In the press room we gathered around the TV monitors, goggle-eyed and mystified, as Voyager once again revealed the surface of a bizarre and dazzling new world. The scene was much the same in the imaging team office, where prominent scientists were observed hopping up and down, saying things like "Boy oh boy oh boy oh boy!" As each new image arrived, there were shouts and gasps and giggles of amazement. Christmas morning on Triton.

Although many of the "instant science" interpretations (both in the imaging office and in Von Karman) turned out to be quite accurate, the overall complexity of the distant moon was daunting. Triton looked like a collage of every other weird terrain Voyager had ever seen. With its nitrogen frost, frozen lakes, and surreal "cantaloupe" texture, Triton couldn't have provided a

On the day of the closest approach to Neptune, the imaging team planned for a sleepless but exciting night.



more fitting finale. The flyby capped what Stone described later that morning as "the most exciting night I can remember of any of the Voyager encounters."

But the mission was far from over. For the "particles and fields" people—scientists who study the behavior and interactions of subatomic particles and the magnetic fields of planets and stars—the really interesting part of the mission was just beginning. The Voyagers are headed outward, toward the heliopause, the distant boundary of the solar wind. Sometime during the next decade or two—no one is sure exactly when—the spacecraft will cross the heliopause and enter the unexplored realm of interstellar space.

Thanks in part to skillful ground control, the aptly named Voyagers have outlived their projected lifetimes.

In the meantime, the scientists will try to make sense of the planetary magnetic fields already probed by the Voyagers. The Neptune results were "extremely exciting," according to magnetic fields principal investigator Norman Ness, a researcher at the University of Delaware's Bartol Research Institute and a member of the project since 1972. Ness and his colleagues had no pictures, but their results were as impressive as the imaging team's. Jupiter was found to have a very strong magnetic field whose north-south axis was, like that of Earth, offset from the planet's axis of rotation by about 10 degrees. But Saturn's modest field was almost perfectly aligned with the rotation axis, a finding that contradicts fundamental theory. "We still don't understand that," says Ness.

Ness was surprised to discover that Uranus even has a magnetic field, and still more surprised to find that it is off-

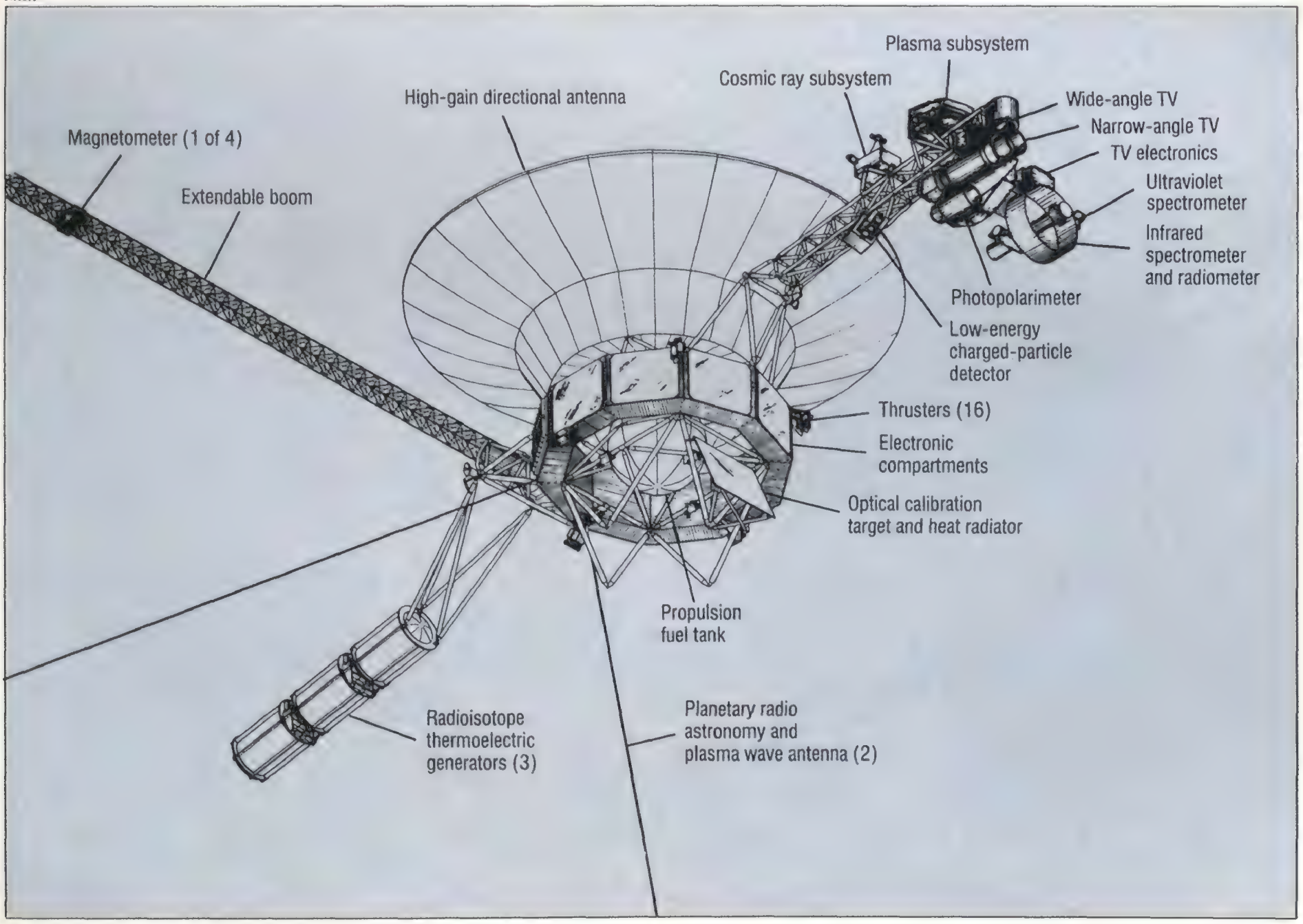
Uranus

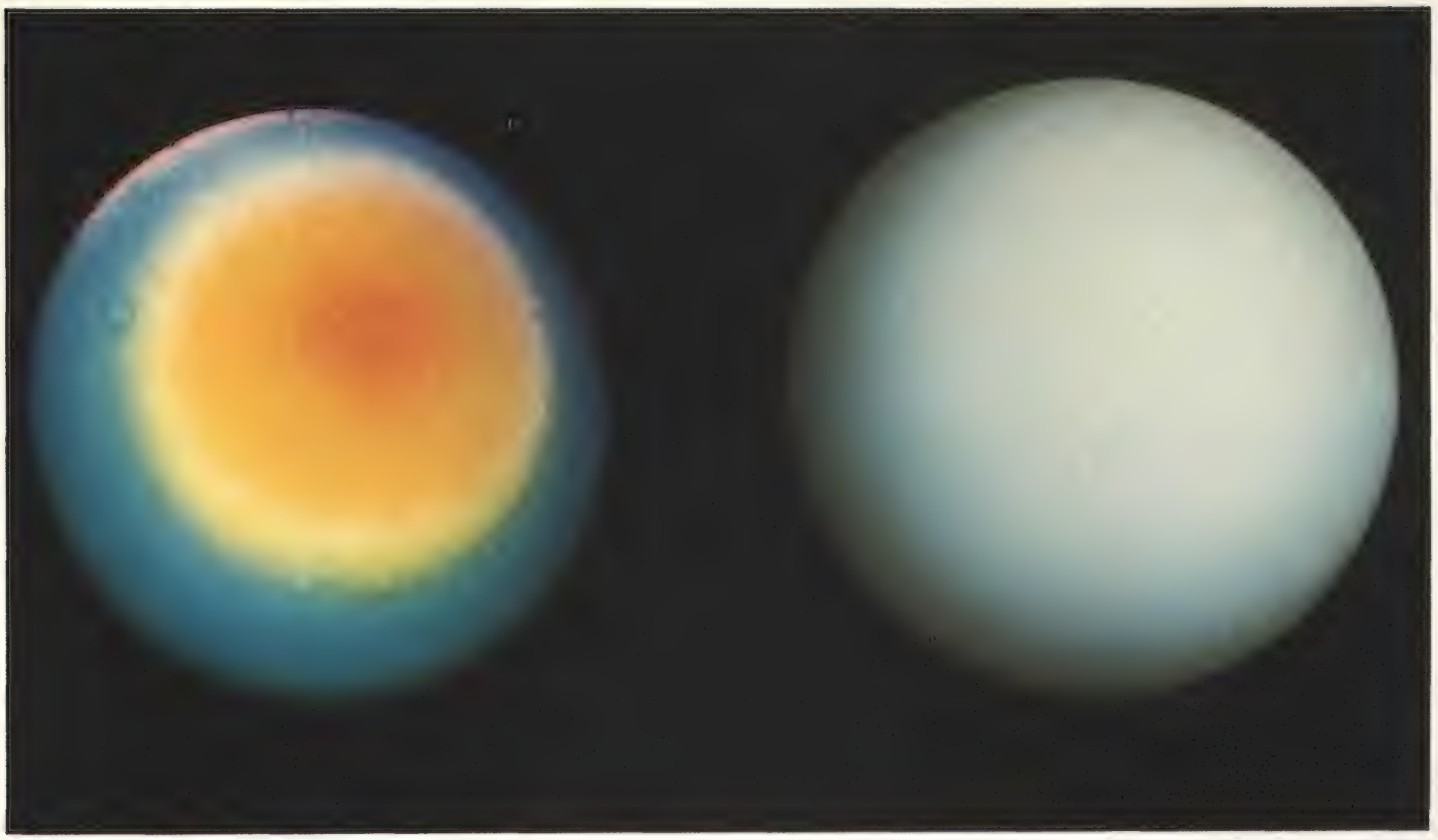
Voyager 2 continued alone to Uranus. The data didn't reveal much in true colors: the false-color images show the distributions of different gases in Uranus' atmosphere.

set from the rotation axis by more than 50 degrees. Because the entire planet is tilted on its side, probably as the result of an ancient collision with another body, "we thought the tilt of Uranus' magnetic field was another unique feature of the planet that was related to its rotation axis being so odd." So it was yet another surprise to find that Neptune's magnetic field was also offset by 50 degrees. "When you see almost the *same* magnetic field—oh, boy, this is spectacular!" exclaims Ness. "It offers us a wonderful opportunity for comparative planetary magnetism studies."

Neptune's rings were having a similar effect on the small group of planetary ring theorists. Voyager found that rather than the expected arcs, Neptune

NASA





actually has four complete—but nevertheless strange—rings. Most of the ring material is concentrated in short, clumpy segments, and ring scientists would like to understand why.

Their field is a new discipline of science, made possible by the discoveries of Voyager. Until the year of the probes' launch, Saturn was the only planet known to possess rings. Then Earth-based observers discovered nine narrow rings around Uranus, and Voyager 1 revealed a wispy ring around Jupiter. Later a second Jovian ring was discovered by detailed analysis of Voyager data, and astronomers reported ambiguous evidence of Neptune's arcs. "We didn't know anything about rings in 1977," says Carolyn Porco of the University of Arizona. "We just basically knew they existed. I think 95 percent of what we know about ring systems was discovered by the Voyager spacecraft."

Saturn's rings remain the most spectacular and scientifically challenging. With thousands of ring features, some of them bizarrely eccentric and twisted, Saturn is an El Dorado for ring scientists. The theorists feel that they are beginning to understand the mechanisms—such as companion "shepherding moons" and spiral density waves—that create and maintain the complex structures of planetary rings.

For their part, Voyager's geologists and atmospheric scientists have more than 40 planetary bodies to ponder. Voyager discovered six moons of Neptune, but many of the scientists, like David Morrison, rank Jupiter's moon Io, with its spuming sulfur volcanos, as "thrill number one." As the Neptune encounter drew to a close, Morrison reflected, "Something like Triton is exciting, but if you think of sheer impact, we had no expectation of catching live volcanos on Io. Even if we caught live volcanos somewhere else, the first time is always going to be the one that just blows your mind." In fact, Voyager *did* catch live volcanos somewhere else. A month after the encounter, imaging analysis found a volcano erupting on the surface of Triton.

A graduate student at Saturn, Carolyn Porco was a full-fledged member of the team by Uranus.

The surfaces of the many moons have already caused a revolution in the field of comparative planetology. "When the mission started," says Morrison, "I think very few people had any appreciation, at either an emotional or intellectual level, of the variety of planetary bodies, in particular the satellites. We've just been overwhelmed with a recognition of the variety of types of objects, the kinds of processes at work, the diverse evolutionary paths the different objects have taken."

The Voyager mission has not only transformed planetary science, it has touched the lives of everyone associated with the project. During each encounter, Judy Nelson took a leave of absence from her job as a secretary at Lockheed

Voyager scientists Brad Smith (left) and Ed Stone had reason to cheer after the Neptune encounter.

and came to work in the press room at JPL. "I think that we need good scientists, and we need good secretaries," she explains. "If I can do the little jobs, then the people who are doing really important work may have more time to do it."

During Voyager 2's encounter with Saturn, Nelson was expecting her first child. Her "mission baby" is now eight years old and knows that he has been on a journey to Saturn. "I have in his photo album a picture of the badge I wore at the time," she says, "because it had, also, his name on it. I've explained to him that he was with me."

Mission babies like Nelson's will grow up in a world that takes for granted the knowledge gained by the Voyagers. The outer solar system is now familiar, if still mysterious; only Pluto remains to explore for the first time. Future missions may increase our understanding, but they can never duplicate the achievement of Voyager. "It will never happen again like it's happened this time," says Porco. "We will never approach a planet being in the same state of ignorance and innocence. We'll go back . . . but it will never have the same romantic feeling that Voyager had."

Porco has a special appreciation of the uniqueness of Voyager. "I was just a graduate student when Voyager went by Saturn," she says, "and there was so much to do and so many new phenomena that all these sexy topics fell in my lap." The Saturn data formed the basis for her doctoral thesis, and by the time of the Uranus encounter she had become a full-fledged member of the imaging team (and one of just seven women among over 170 Voyager scientists).

Voyager "launched my career," says Porco. For other scientists, the Neptune encounter marks the end. Imaging team leader Brad Smith will soon retire to the island of Hawaii, a stone's throw from the place where another of history's great explorers, Captain James Cook, first landed.

Surely the Voyagers' journeys, like Cook's, will be remembered in the centuries to come. "Voyager will be remembered with the same respect and awe that the journeys of Columbus are remembered," says Porco. "I can't imagine that it's not going to bring a tear to the eye of people a hundred years from now, knowing what we did."

Voyager has already brought tears to

more than a few eyes. Throughout the mission, many of us had cringed when reading anthropomorphic press accounts about the "plucky" or "intrepid" "little spacecraft that could." But as the Neptune encounter wound down, none of us could help feeling sentimental about that marvelous machine.

Already technological antiques—journalists at JPL wrote their stories on laptop computers that were ten times as powerful as the ones aboard the spacecraft—the Voyagers have survived due to the heroic but generally unsung labors of the mission engineers and operations staff. Designed to last for just two planetary encounters and five years in flight, the spacecraft now seem likely to keep transmitting important data well into the second decade of the next century. Despite suffering major malfunctions that might have killed it a year before its Jupiter encounter, Voyager 2 is in many respects a better, more efficient spacecraft now than when it was launched. To cite just one example, Voyager 2's primitive computers were reprogrammed en route, enabling the craft's imaging system to take the long exposures necessary at Neptune, where sunlight is 1,000 times dimmer than it is

Geologically diverse Triton nearly stole the show from Neptune. Dark streaks may mark nitrogen volcanos.

Voyager's Greatest Hits

Voyagers 1 and 2:

- Provided the first detailed observations of Jupiter, Saturn, Uranus, and Neptune; measured wind speeds (up to 1,000 mph on Saturn) and temperatures in their atmospheres; characterized atmospheric circulation patterns; and established precise sizes and rotation periods of those bodies.
- Discovered auroras and lightning in the atmosphere of Jupiter.
- Discovered the magnetic fields of Uranus and Neptune; directly measured magnetic fields of all four "gas giant" worlds; observed the solar magnetic field and solar wind in the outer solar system.
- Discovered the existence of the Jovian rings; found two new rings around Uranus, at least four complete rings around Neptune, and tens of thousands of rings encircling Saturn; made possible detailed analysis of structure and dynamics of planetary ring systems.
- Observed active volcanos on the Jovian moon Io and a nitrogen volcano on the Neptunian moon Triton.
- Discovered at least 22 new moons (Jupiter, 3; Saturn, 3; Uranus, 10; Neptune, 6).
- Photographed at a resolution of 10 miles or less the surfaces of 20 satellites; observed unique geological characteristics of icy bodies in the outer solar system.
- Measured the density and temperature of the Saturnian moon Titan; discovered that the atmosphere on Titan is 90 percent nitrogen.
- Carried out ultraviolet astronomical observations of stars during cruise between planets.
- Will cross the heliopause, outer limit of the solar wind, and make direct measurements of the interstellar medium.
- Returned some 115,000 images of planets, moons, and rings.
- Cost a total of approximately $865 million. The average American taxpayer has spent about 20 cents per year for the tour of the outer solar system.

Its encounter over, Voyager looked back at Neptune and Triton, dimly lit by the distant sun.

on Earth. "I can't believe these guys," Brad Smith said of the mission engineers during the Uranus encounter. "They fix things halfway across the solar system!"

Strictly speaking, the two Voyagers are "unmanned" spacecraft. Yet they will carry, if not humans, then at least the human spirit to the stars. They will wander forever through the galaxy, unless, by some astronomical long shot, some other spacefaring species should happen upon those emissaries of mankind. If they do, they will find aboard the spacecraft a gold-plated phonograph record on which some of the sights and sounds, voices and music, of planet Earth are preserved.

One of those voices belongs to rock 'n' roll legend Chuck Berry, whose 1958 classic "Johnny B. Goode" is one of the songs included on the Voyager record. Berry canceled another gig so he could be at JPL, where he entertained a joyful, cheering throng on the central mall during a farewell bash the Planetary Society sponsored for the Voyager family. Releasing a decade's worth of emotions, the men, women, and children of Voyager boogied and bopped and howled at the moons as Berry performed. "Go, Voyager, go. . . ."

At the 54th and last Voyager press conference, Ed Stone quoted another poet in final tribute to the mission. "Not fare well," T.S. Eliot wrote, "But fare forward, voyagers."

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The Autogiro and Its Legacy

The principles of the "flying windmill" live on in the helicopter.

by Richard Aellen

And although it looks like something Jules Verne thought of, it will actually land in one's flower garden—or, if one is fussy, in one's neighbor's flower garden.
—*The New Yorker,* November 1, 1930

If you missed dancing to the tunes of Tommy Dorsey or buying gasoline with a ration card, you may not remember the autogiro. Once heralded by a U.S. senator as "the greatest development in aviation since Orville Wright taught men to fly," the autogiro was an odd-looking hybrid of airplane and helicopter. No other aircraft captured the public's imagination so quickly or vanished so rapidly into oblivion. Perhaps it was inevitable. After all, no one—not even Juan de la Cierva, its inventor—set out to build an autogiro.

Inspired by Louis Blériot's 1909 flight across the English Channel, the young Cierva vowed to make aeronautics his life's work. In 1912, at age 17, while studying at the engineering college in Madrid, Cierva produced his first powered aircraft—a modified Sommer biplane called the *El Cangrejo.* With no

In the early 1930s, Detroit News *reporters raced to breaking stories in one of the paper's two Pitcairn autogiros.*

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After Juan de la Cierva (left) sold licensing rights to Harold Pitcairn, autogiros flourished in the U.S.

money left to varnish the Red Crab's fabric wings and fuselage, Cierva resorted to a coating of glue, which eventually dissolved in the rain. The biplane soon disintegrated. The following year Cierva built a small monoplane that crashed twice before its designer put aircraft production on hold and concentrated on his studies. When the Spanish government announced an upcoming military aircraft competition, Cierva began building a massive bomber, the three-engine C-3, financed by his father and a wealthy friend.

The C-3 made its first flight in July 1919. During a low-altitude turn, the craft stalled and crashed. The pilot was unharmed; the C-3 destroyed. "But what struck me most forcibly at the time," Cierva later wrote in his autobiography, "was the fact that a big and expensive airplane should come to such a bad end simply because it could not fly slowly in safety while close to the ground.... I found I must go all the way back to the essential theory of flight and discover whether it could be applied entirely differently to the development of a successful flying machine."

An airfoil, or wing, is the basic structure for developing lift. To generate lift, it must move through the air with sufficient speed. But must fuselage, pilot, and passengers travel at the same speed as the wing? Maybe the wing could travel independently—if it were a rotary wing.

This, then, was the genesis of the autogiro—not a desire for vertical flight or a quest for a helicopter, but the search for a safer aircraft based on the principles of the rotary wing. To Cierva, the helicopter would forever be limited by its aerodynamic complexities. The few designs that had actually gotten airborne were unstable and uncontrollable. And no one had yet managed to solve the problem of torque, induced by the engine that powered the helicopter's rotors. Engine torque made a fuselage spin clockwise in reaction to a rotor's spinning counterclockwise. But what if the rotor were unpowered, like a windmill, and able to turn freely as the aircraft was pulled through the air by a propeller?

In 1920 Cierva began to experiment. He knew his biggest problem would be the rotary wing's imbalance of lift. The speed of the advancing blades, coupled with the forward speed of the aircraft, would exceed that of the retreating blades, creating greater lift on one side of the aircraft. There was also gyroscopic force to contend with: a spinning mass resists being tilted out of its plane of rotation.

Cierva's first attempt to solve both problems resulted in an autogiro with two counter-rotating rotors, one atop the other. This, he reasoned, would counterbalance gyroscopic force, and with both rotors turning at the same rotation rate, lift would be equalized. But the downwash of the top rotor halved the bottom rotor's speed, destroying the delicate balance. The autogiro lurched over onto its right side.

Cierva abandoned the dual-rotor system and concentrated on changing the angle of the blades as they spun clockwise around the hub. The greater the angle, the more the blades would bite into the air and generate lift. Cierva used a cam arrangement to adjust the blades so they had less of an angle as they moved forward and more as they retreated. The new autogiro tipped over before it got off the ground. He installed ailerons on outriggers in line with the propeller slipstream for better lateral control. This autogiro sort of hopped rather than flew, and it too occasionally tipped over, but Cierva was thrilled—even an uncontrollable hop meant he was on the right track. He switched to models powered by rubber bands to further test control theories. One with four blades of rattan flew splendidly, yet the full-size machines would not.

In 1922 Cierva was daydreaming through a performance of *Aïda* when the answer came to him. The model's rotor blades were flexible—they automatically compensated for varying amounts of lift. As the advancing blades developed greater lift, the force of the lift caused them to bend upward in response. As they did, the angle at which they met the oncoming air changed, effectively diminishing lift on the blade. The retreating blades did precisely the opposite, increasing lift proportionately.

The rotor blades of Cierva's next autogiro were attached to the mast with

Amelia Earhart flew coast to coast in Beech-Nut's brand new autogiro but crashed in Kansas on the return trip.

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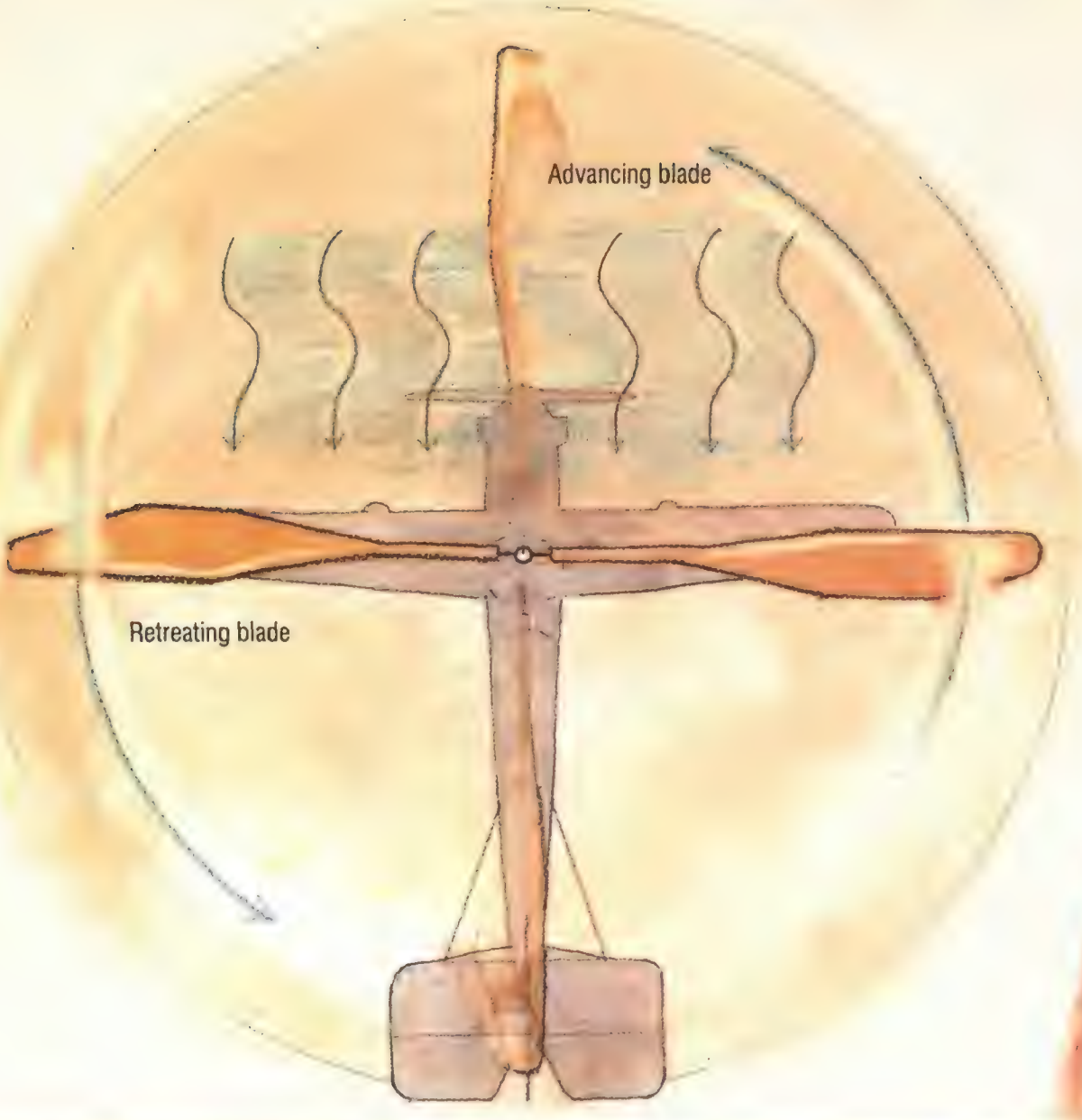
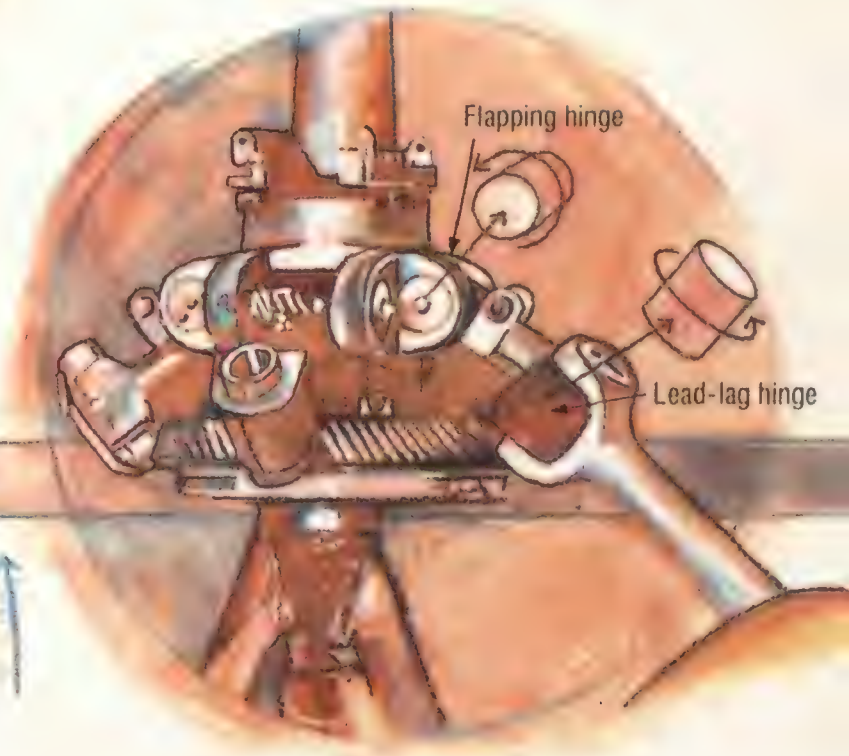
WEB BRYANT

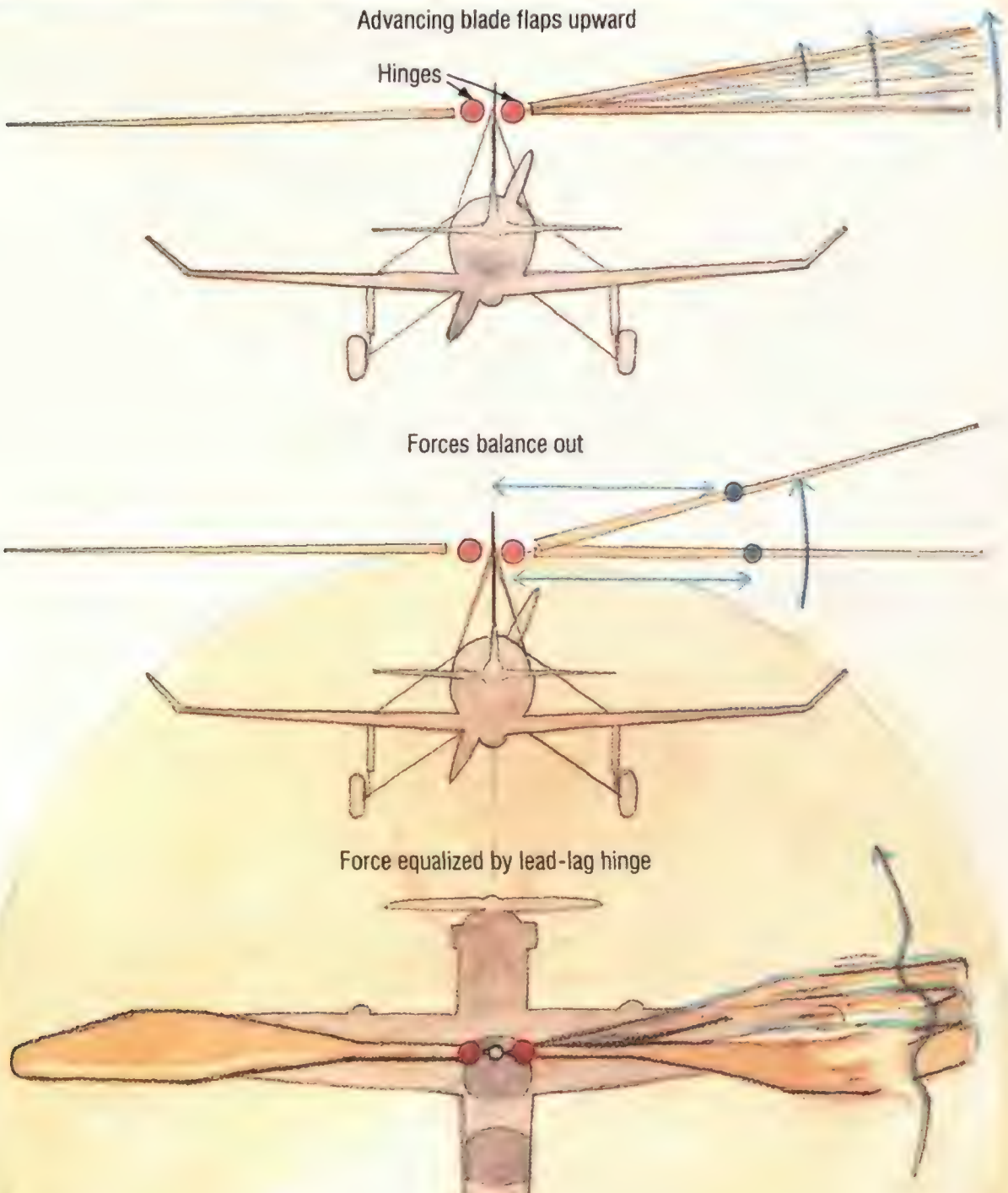


How Cierva Stabilized His Autogiro

The Problem

Rotary-wing aircraft confront a problem not shared by fixed-wing aircraft: the rotation of the rotor blades creates an imbalance in lift forces on the blades. As the craft moves forward through the air, the flow of air over the advancing blade is faster than the flow over the retreating blade. The advancing blade therefore produces more lift than the retreating blade, and the imbalance results in a greater upward force on the advancing blade—which is why Cierva's first designs tipped over.





The Solution

When a set of hinges is installed to allow the blades to flap up and down, the advancing blade is free to rise in response to the increased lift exerted on it. When it rises, the lift decreases and the blade settles into a state of equilibrium in which the forces balance out.

However, when the blade is allowed to flap upward, the distance between the center of its mass and the center of rotation decreases. Like ice skaters who spin faster when they pull their arms in, the blades want to speed up.

When the blades are affixed to the rotor hub there is no way for the force created by this acceleration to be relieved. So Cierva installed a second set of hinges that allow the blades to lead or lag their normal position. The modern rotary wing—with fully articulated blades—was complete.

—George C. Larson

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Equipped with folding rotor blades, Pitcairn's "Roadable" model promised to make commuting a breeze.

hinges that allowed some vertical play. Equipped with these hinged, or articulated, blades, the autogiro made a short but sweet successful flight in Madrid in January 1923. The articulated blade, which four years later was fitted with a second set of hinges that balanced the fore-and-aft forces on the blade by allowing horizontal play, was the key to Cierva's success (see diagram on the previous page).

Two years later the designer moved to Great Britain, where he and British industrialist James Weir formed the Cierva Autogiro Company to oversee autogiro production. Widespread interest had also led to licensing agreements in Germany, France, the Soviet Union, and Japan. In the United States a licensing agreement was purchased by Philadelphia aircraft designer Harold Pitcairn, whose Pitcairn Mailwings were plying the New York-Miami mail route. In 1929 Pitcairn sold the profitable airmail route—which later became Eastern Airlines—and formed the Pitcairn-Cierva Autogiro Company of America.

Pitcairn and Cierva had much in common. Both were born to prominent families and both had built flying machines as boys. More importantly, both looked upon the autogiro as a safe, inexpensive, easy-to-fly aircraft. They envisioned it as a Model T of the air, an aircraft within the means and abilities of the general public. When the Autogiro Company of America started designing and building autogiros, the dream seemed well within reach. "They will deliver far places from loneliness," Cierva wrote, "and make near neighbors of the communities of a continent."

At first the autogiro's offbeat, irreverent design captured the public's fancy—the press called it "the flying windmill." Autogiros landed on rooftops, sprayed crops, carried newspaper reporters to breaking stories, and touted chewing gum and spark plugs. "That's the answer!" announced early helicopter enthusiast Thomas Edison in 1930 when he saw the autogiro fly at Newark, New Jersey, at speeds ranging from 20 to 115 mph and then land nearly vertically. Amelia Earhart flew one to a record 18,415 feet and pronounced that its safety and ease of control "should be of real influence in bringing women into aviation." The autogiro became the ultimate fad in a decade epitomized by marathon dancers and goldfish swallowers.

In 1931 President Herbert Hoover awarded the Collier Trophy to Harold Pitcairn and his associates for "the greatest achievement in aviation, the value of which has been demonstrated by actual use during the preceding year." An autogiro swooped over the Capitol and landed on the south lawn of the White House for the ceremony. Two years later, an autogiro accompanied Admiral Richard E. Byrd on an Antarctic expedition.

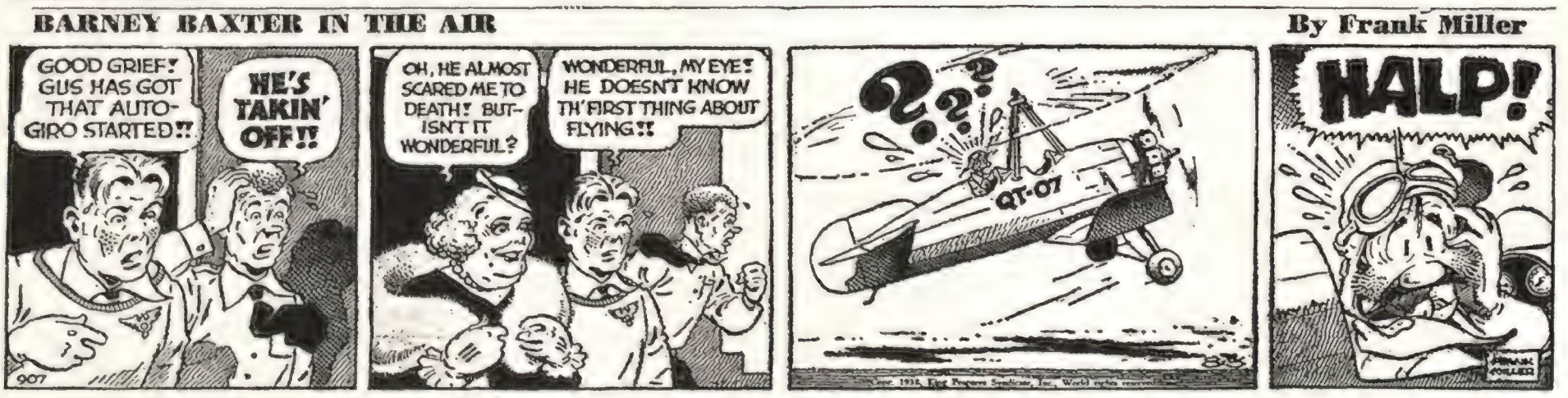
Harold Pitcairn knew that beneath the hoopla the autogiro was making great advances in rotary wing technology. By now Kellett Aircraft Corporation and Buhl Aircraft Company had been licensed by Pitcairn to design and build autogiros. But in 1933 Pitcairn discontinued his involvement in sales and manufacturing to concentrate on research and development. One problem was that the Depression had sharply curtailed American buying power. Equally significant was the restless, inventive mind of his friend Cierva. "In many instances," Pitcairn later explained, "his ideas made existing machines out of date before they could be put in production. This was an excellent thing for the Autogiro, but sometimes embarrassing for its manufacturers."

By 1936, great achievements notwithstanding, the autogiro's glory days were over. To people who couldn't even make car payments, the notion of an autogiro parked beside the family Packard was a joke. And that December, the autogiro effort lost its leader—Cierva died aboard an airplane that crashed just after takeoff.

Despite sluggish sales, research and innovation continued. Nearly 200 Cierva-Pitcairn patents were issued to the Autogiro Company, most dealing with blade design and rotor control methods. Particularly important were Cierva's systems for changing the angle of the rotor and its blades in flight. The "direct control" autogiro employed a tilting rotor hub that allowed the pilot to

America's fascination with the autogiro peaked when the craft appeared in the comic strips.

COURTESY KING FEATURES



COURTESY PITCAIRN AIRCRAFT ASSOCIATION (2)

control pitch and roll with the rotor instead of the ailerons and elevator, which were ineffective at low airspeeds. And collective pitch, which altered the angle of all the rotor blades simultaneously, enabled the autogiro to leap 30 feet. The engine would spin up the rotor to a high rotation rate but with the blades pitched too flat to develop lift. When the rotor was "declutched," or disengaged from the engine, angled hinges on the rotor hub caused the blades to bite into the air and pull the autogiro straight up until the propeller pulled it forward and the blades returned to a lesser pitch for horizontal flight.

Cierva's genius lay not in conceiving direct control and collective pitch—crude versions had been employed in early autogiro and helicopter experiments—but in perfecting designs that had practical applications, breakthroughs that would later prove indispensible to the helicopter. Eventually the autogiro lacked only one capability of the helicopter: sustained vertical flight. Unlike the helicopter, the autogiro's rotor was never powered in flight, which limited its vertical performance to brief "jump" takeoffs and nearly vertical descents. Because the rotor was unpowered and could only be turned by the aircraft's forward motion, the autogiro could not hover. Cierva had believed that for most applications, vertical flight wasn't worth the resulting increase in cost, maintenance, and handling difficulties and the decrease in safety and performance.

Ads targeted the landed gentry as customers for Pitcairn's sporty two-seat autogiro—the ideal transport to the hunting lodge, the country club, the horse show, the football game, and the golf course.

Despite these drawbacks, helicopter research continued, with early designs ranging all over the lot. Most were awkward skeletal machines crisscrossed with drooping drive belts and gnashing power chains, topped by any number of fat, fan-like rotors. It wasn't until September 14, 1939, that Igor Sikorsky's VS-300 briefly hovered a few inches off the ground in the familiar configuration seen today: a powered main rotor overhead and a small rotor in the tail to counteract the main rotor's torque.

Sikorsky's landmark flight sounded the death knell for the autogiro. Two weeks earlier Germany had invaded Poland, starting World War II, and the military lost interest in autogiros and instead commited to the helicopter. But the autogiro's technology emerged triumphant. In doing so, it also became the focus of a 26-year-long lawsuit.

Sikorsky's new machine needed the sophisticated control systems developed by Cierva and Pitcairn and patented by the Autogiro Company, so Sikorsky's parent company, United Aircraft Corporation, became a licensee of the Autogiro Company of America. Newer companies, however, were reluctant to enter into similar licensing agreements. Why should they pay an autogiro company for technology that helicopter designers could have eventually come up with? What would happen if they ignored the patents—would Harold Pitcairn really sue? The Bell, Kaman, Piasecki, and Hiller companies waited to see what would happen and

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When the Detroit News *covered stories in its autogiros, the craft was all the rage (above). Today, a 1931 model that touted spark plugs from Maine to Mexico has been restored by Stephen Pitcairn and stars mainly at rotorcraft rallies (right).*

more importantly, to whom.

By this time, the U.S. government, on the verge of issuing millions of dollars in helicopter contracts in response to the onset of the Cold War, realized that manufacturers faced a five percent royalty to Pitcairn on each machine—a sum that would undoubtedly be passed on to the purchaser. Like an older brother losing a card game, the government decided to change the rules.

Military contracts had a provision that held the government harmless in cases of patent infringement. The new rule reversed this liability: now it was the manufacturers who would be held harmless. All they had to do was build and deliver helicopters as inexpensively as possible. If Pitcairn wanted to challenge this, he'd have to sue the U.S. government.

This was an unexpected setback. Pitcairn had assumed that royalties from the burgeoning helicopter industry would help recoup part of the more than $3 million his company had spent on rotary wing development. "If I had been aware that the government would become so hostile to the payment of reasonable royalties," he wrote later, "our Company certainly would not have embarked on the development of rotary-wing aircraft."

Pitcairn filed a lawsuit against the U.S. government on September 21, 1951. The case was extremely complicated, largely due to the inherent complexity of rotary wing technology. Much of the testimony before the U.S. Court of Claims reads like an advanced course in aerodynamic engineering. Further complicating matters were the intricacies of patent law and the intransigence of the government lawyers.

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On July 23, 1977, the court found that 11 autogiro patents had been infringed in 59 claims. Pitcairn did not live to see the victory: he had died in 1960 when his handgun misfired during a nightly security check of his Pennsylvania home. His estate was awarded $14.4 million in unpaid royalties and $17 million in "delay compensation."

But in the quarter-century since the opening salvos of the court battle, the autogiro had completely lost the war. Aside from a brief resurgence in the 1960s and '70s, the autogiro lost all momentum. Today only hardcore enthusiasts keep it alive with annual fly-ins. Inevitably the star of these rallies is Stephen Pitcairn and his navy and yellow PCA-2, which in the autogiro's heyday advertised Champion spark plugs to a captivated public.

The Cosmos According to McCall

The dean of space artists paints tomorrow today.

by Karen Jensen

Photographs by Jim Richardson

A fellow artist calls McCall "the man from the future," part of which takes shape near his Arizona home.

One day in 1979, Robert McCall was in the midst of painting a huge mural at the Johnson Space Center when Chris Kraft, then the center's director, made him a proposition. "Bob, you're painting this astronaut in the shuttle space suit," McCall recalls him saying. "You ought to know what it feels like."

With the assistance of several men, McCall wriggled into the suit, one similar to those used for extravehicular activity, and the helmet was lowered into place. He stared out the visor, posed for a photograph—and felt claustrophobia setting in.

"I would have loved to have been an astronaut, but . . . I prefer being an artist," says McCall, who today is the reigning space artist in the United States, perhaps the world. Millions of people have seen his most famous work: a six-story acrylic titled "The Space Mural—A Cosmic View," located on a wall of the National Air and Space Museum in Washington, D.C. Millions, too, have seen other examples of his art, though they may not realize it: McCall's work includes commemorative stamps and NASA mission emblems, as well as posters and conceptual artwork for such films as the science fiction great *2001: A Space Odyssey* and Disney's *The Black Hole.*

McCall may also be the space program's number one booster, an astronaut groupie of the highest degree. He peppers his conversation with the names of astronauts, many of whom have become friends, and their photographs and other space memorabilia are strewn around his Arizona studio. The license plates on his silver Mercedes-Benz 450 SL read "Space 1."

His devotion to space and its conquering heroes is not mere showmanship, however; it is as sincere and pure as a schoolboy's crush on his teacher. His works are unabashedly patriotic, heroic, romantic. McCall believes that our future lies in space and that it is his duty to share that feeling with others. "I want the viewer to somehow get some kind of an optimistic lift about the mystery and magic and wonder of the universe, and its limitlessness, and the beauty of it, and astonishing magic of it all," the artist explains in a typically McCallian flow of words. "The word 'magic' I'm using more and more, it seems, because it seems to be a very descriptive word that serves me very well in expressing my feelings about the universe. Pure, pure magic. The best kind of magic."

To convey this feeling, McCall chooses to favor the enticing over the realistic in his work. "I continue to strive to paint [space] more and more appealingly," he says. He gestures to a large study for an upcoming work—nearly a completed painting in itself—pointing out the warm blue background: "very cerulean blue," he notes in his soft, Midwestern-accented voice, "with stars sparkling and a big silver creamy galaxy spiraling off over here on the right . . . . And it's very, very appealing. So I'm not painting it realistically at all. It's an impression—impressionism."

Although McCall participated in both the Air Force's and NASA's art programs, painting everything from aircraft carriers to the space shuttle, the bulk of his paintings are of missions that have yet to occur. In McCall's world the space station is already in use and shuttles regularly dock there with cargo and

passengers. A manned base on Mars teems with activity, and spacecraft carry out missions NASA has yet to imagine. "You know, Bob is such a strong supporter of the future in space and he's got such an imagination," says Gemini and Apollo astronaut Eugene Cernan, "that the things he does in some of his paintings are things that seem a little bit far out today, but are truly things that *will* happen someday."

Andrei Sokolov, a prominent Soviet space artist and an acquaintance of McCall for over a decade, puts it more poetically. "I think that he is an outstanding artist," Sokolov says, "but the main point about him is that he is the man who already lives in tomorrow. It happens seldom, but it is possible: he is the man from the future."

McCall's movie work isn't restricted to science fiction: he also did the conceptualizations for the World War II epic The 1000 Plane Raid.

In "Ascension," the artist tried to communicate a feeling of exuberance. In a thematic departure, he also wanted to hint at the hostile conditions of space.

Since he was a boy growing up in Columbus, Ohio, McCall has been fascinated by art, by machines, and by heroic figures. "I drew and painted the pictures that excited me," he says, "and the things that excited me were airplanes and ships at sea and military tanks and men in conflict." One image that appeared over and over in his early work was that of the knight in armor, and McCall sees a kinship between the mounted warriors that fascinated him as a child and the well-armored fighter pilots and astronauts that captivate him as an adult.

After two years at the Columbus School of Fine Arts, which he attended on scholarship, and a succession of jobs that to one degree or another tested his artistic skills—as artist for a sign shop, an electric company, and an advertising studio—as well as a stint in the Air Force, the 29-year-old artist decided in 1949 to move to New York City to try to make a living as a magazine illustrator.

The experience was initially unsettling. "Suddenly I was in an environment where there were so many other very talented young people who had gravitated to that same locale for the same reasons that I had, and I realized how, oh, kind of modest my talent was," he says.

His big break came in 1955, when *Life* magazine assigned him to illustrate a serialization of Walter Lord's *Day of Infamy,* about the attack on Pearl Harbor. The assignment took advantage of his skills and interests and brought him greater recognition. Soon his paintings of airplanes began earning him new clients. It seemed McCall had found his niche.

But he hadn't, not yet. He found it after *Life* assigned him, beginning in 1960, to illustrate articles on spacecraft of the future, the U.S. space program, and Soviet spacecraft. As a handful of American pilots were being transformed into astronauts, the painter of airplanes was being transformed into a painter of spacecraft.

"So it was an easy, natural transition," McCall says. "But beyond that, even if *Life* had not done that, I was very interested in the space program." Firms that were gearing up to produce equipment for the space program hired McCall to illustrate their advertising. Other magazines began requesting his work, and it wasn't long before he had produced his first postage stamp and saw the publication of a book featuring his work. In the small but burgeoning field of space art, McCall had found what he calls his "ultimate niche."

Hardware still tends to take center stage in his work today, just as it did in his earlier paintings. As space artist Ron Miller puts it,

It's not on canvas, but it is a McCall: his stained glass windows create a 360-degree panorama for the Valley Presbyterian Church in Scottsdale, Arizona.

for McCall "the romance is in the machinery, which in some cases can be as wholly made up as some of [other space artists'] landscapes are. In fact," Miller adds, "some of his spaceships have really no basis even in technical reality or scientific reality. He just made what he thought was a nifty-looking spaceship. He has an ability to add a patina of verisimilitude to his machinery, so that even the most fantastic devices look like they could work. That's where I think his real strength lies: in making future technology believable."

By 1971 McCall felt secure enough in his career to leave New York. He gave up Manhattan for Arizona, where he now lives in affluent Paradise Valley with his wife, Louise. Also an artist, Louise occasionally advises her husband on his paintings. Yet she insists that having two artists in the same household is not one too many, as could easily be the case. Indeed, sometimes it is hard to tell where art ends and the rest of their lives begins. While the couple was preparing the house for a guest recently, something McCall was doing caught his wife's eye. "Oh, you like the circle on top of the square, do you?" she asked, and the two artists stepped back, hands cupping their chins, to contemplate the question. "Well, all right, I guess that looks nice," Louise concluded, a little uncertainly. This said, her husband, having opted to place square cloth napkins under their dinner plates rather than the rectangular placemats Louise had just fished out of a cabinet, finished setting the table.

With a charming wife, a beautiful home, and a secure place at the top of his profession, McCall can come across as a man who has it all. But two goals have eluded him.

During World War II, McCall enlisted in the U.S. Army Air Corps with the aim of becoming a pilot. But a physical revealed the artist to be, of all things, color blind. Though a subtle kind of color blindness—a slight skewing in the reds and greens—it was enough to disqualify him. He wound up training as a bombardier.

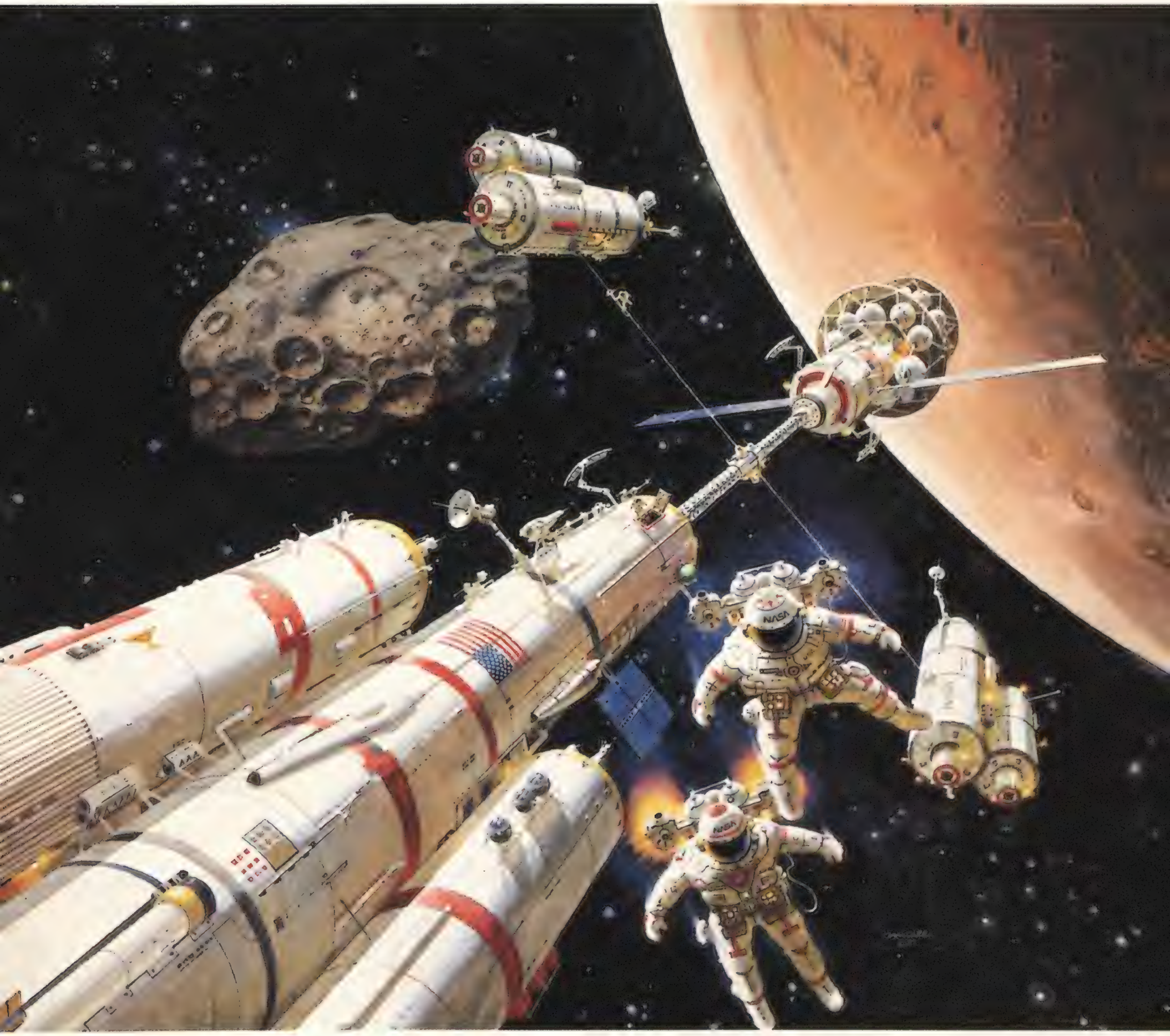
And when NASA was exploring ideas in 1983 and '84 for sending citizens into space aboard the shuttle, McCall was rumored to be the space agency's leading candidate for first artist in space. But the explosion of *Challenger* in 1986 forced NASA to put its plans for sending non-astronauts into space on indefinite hold.

"I wish that could have happened," McCall says. But then he adds that at age 70 he feels he isn't in good enough shape for a space mission anyway. "So I don't have to worry about that. I would have had some worrying, I'll tell you." His voice, however, conveys more regret than relief.

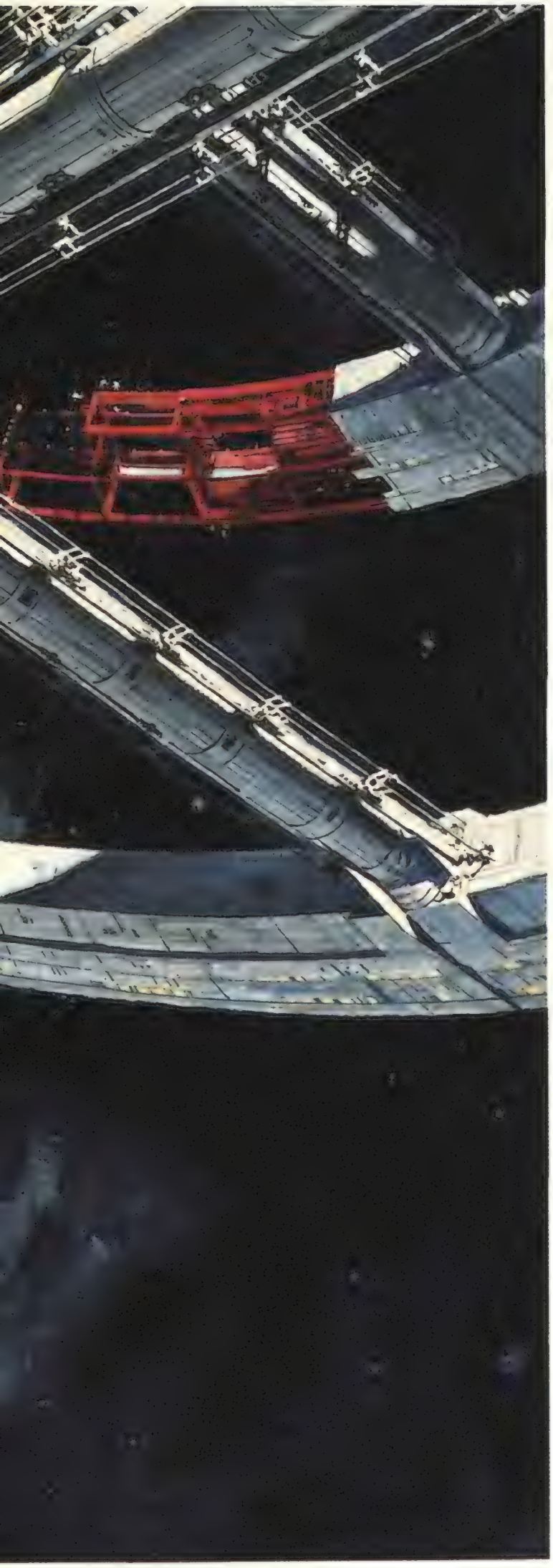
When asked to name his favorite work, McCall doesn't hesitate. It's the one that was the biggest challenge, the one that gave him the most satisfaction, the one that was, in his words, "fun, fun, fun"—his mural for the National Air and Space Museum. The importance of the project, its setting, its message, its sheer *size* were all tremendously appealing to McCall. And although he still frets that he didn't get all of it just right—he says he overworked the mural's smaller astronaut figure "and it got stiff on me"—it is the work of which he clearly is proudest.

A former curator of spacecraft at the museum fondly recalls standing near the scaffolding and watching McCall paint in the days shortly before the museum opened in 1976. "Oh, anyone can do this," McCall told his small audience one day, proceeding to demonstrate his technique, then relinquishing his brush and paints. In an excellent approximation of McCall style, the curator

In McCall's world, Mars is a beehive of human activity, as in this mission to Phobos, painted for NASA.



Perhaps McCall's most famous image, this space station was painted for the science fiction classic 2001: A Space Odyssey.



After musing about what we could do if we controlled gravity, McCall started his series of floating cities.

Reality and illusion merge as McCall touches up "The Spirit of NASA," painted at Florida's EPCOT Center.

The "dean of space artists" and his wife Louise prepare for a "Pops in Space" night at the Phoenix Symphony. McCall's modular surface transportation vehicle will get them to a pre-concert party in the artist's honor (right).

contributed a glowing, hazy-looking asteroid to the work. But when he kiddingly asked if he could sign it, McCall told him, "Oh, I think that would be going a bit far."

McCall doesn't collaborate often and when he does it is usually in the well-defined role of master. Louise McCall has contributed to several of his works. She added flowers to his bucolic mural "The Prologue and the Promise," painted for Disney's Epcot Center in Florida. And she designed two floral panels in stained glass to accompany the breathtaking 360-degree windows that McCall created for the chapel of the Valley Presbyterian Church in Scottsdale, Arizona.

One of McCall's more recent projects casts him in a less dominant role. He is collaborating with Andrei Sokolov on a large painting—probably a whole series of them by the time they are done. In spring of 1988 McCall joined Sokolov in his Moscow studio and began preliminary sketches for the work. Sokolov visited McCall's studio a year later to begin work on the painting itself, then returned in August to contribute some more. They expect to complete the painting in Moscow in 1990.

The artists are being careful to avoid offending each other's national sensibilities. "It's hard to balance this," McCall acknowledges, "to balance the painting and make it equally comfortable for Russians who view it and for Americans." While the end result could "produce something less good than either one of us could have done by ourselves," McCall feels that the compromises and concessions they've made may be the best part of it in the end, and that there may be something to be learned from the experience. During a joint mission to Mars, he points out, "our nations will be faced with the same problems, only more complex."

But if these two space art superpowers are collaborating in the name of world peace and cooperation in space, the fact is that they remain, inevitably, competitors.

"I don't know whether I'm better than he is or he's better than I am," McCall says. "I want to be better. I want to be better than anybody, right?" The artist smiles as he says this, for he knows he doesn't sound much like an artist at the moment: more like an athlete, perhaps, or a fighter pilot—or an astronaut.

At last spring's program, the symphony played a medley of space-related themes as McCall's work was projected on a screen. The astronaut (at right of middle picture) is from his favorite work, the mural at the National Air and Space Museum.

THE BONE PICKERS

In the Arizona desert, a different breed of prospector finds the gold in airplane carcasses.

by William H. Gregory *Photographs by Jim Richardson*

When life ends in the desert, a process of recycling begins. Scavengers arrive before the carcass is even cold. Soon the body is stripped clean and returned in another form to the community. This transaction is nature's way of sustaining the environment—its design self-perpetuating, seemingly interminable.

At Davis-Monthan Air Force Base, on the southside of Tucson, Arizona, in the Sonoran desert, a similar process occurs between old military aircraft and local scrap dealers. This ruler-flat stretch of desert in southern Arizona's basin-and-range country might be called the old-airplane capital of the world. Its low humidity, meager rainfall, and hard soil convinced then-secretary of defense Robert McNamara and the U.S. military services to consolidate surplus and retired aircraft at Davis-Monthan in 1963.

Surrounded by 13 miles of fence, Davis-Monthan's Aerospace Maintenance and Regeneration Center today includes on its 2,262 acres more than 2,600 aircraft from the Air Force, Army, Coast Guard, Marine Corps, and Navy. These relics from palmier days are strewn about the desert like a child's forgotten toys, creating bizarre images: stabilizers rear up like roosters' tails; nacelles without engines look like eyeless sockets; folded-over wings give the airplanes the appearance of nesting birds.

Across the road from this desert warehouse, a half-dozen salvage yards ply their trade. For a salvage business to make a profit, location is vital: sites any farther than across the road quickly make transportation too expensive, especially since most of the aircraft are not flyable. Or to be more precise, aircraft classified as combat types are not allowed to be flyable. Jet aircraft that can carry a weapon, from two-seat trainers up to B-52 bombers, have to be dismantled by the buyer. Depending on bid terms, the "modifications"—wings guillotined or nose and tail sections torched—must be made before the carcass can be hauled off the base. It's a simple matter of military policy. Uncle Sam doesn't want used-aircraft dealers selling military aircraft overseas, even to friendly countries.

Surplus aircraft are divided into three

RUSSELL MUNSON

B-52 Stratofortresses form a mosaic in their desert retirement home. The caliche *soil is hard enough that the parked aircraft don't require paving.*

As the owner of an overhaul and repair center, Gordon Hamilton has seen a parade of old airplanes and strike-it-rich prospectors.

categories by scrap dealers: those that are profitable to rehabilitate, those with parts of value, ranging from electronics to wing tanks, and those worth only melted-down scrap value. Most disposals fall into the latter two categories.

The salvage yards draw all kinds of customers. Railroads buy jet engines to burn snow off the tracks. Farmers buy fuel tanks to use as watering troughs. A motor home manufacturer bought thousands of fuel shutoff valves to use as dump valves. Filmmakers are also regular customers. A Hollywood movie like *The Flight of the Phoenix* can be a scrap dealer's bonanza.

Little electronic bits from airplane black boxes are readily saleable, particularly to China and other countries trying to industrialize without the manufacturing base to make miniature precision circuits. Even if not worth anything as chips, electronics have gold-plated connectors, rare earths, and the like that are valuable.

But times have changed for the salvage yards since the fabled goldrush days following World War II. Back then, sparkling new P-51s, B-17s, and P-38s fresh off the assembly line were flown to Kingman in northwest Arizona or to Phoenix near the Navy's Litchfield Park storage site, as well as several other sites. There they were purchased by scrap dealers, demolished, and melted down into drab aluminum ingots.

Gordon Hamilton looks back on those days with a mixture of awe and dismay. As the owner of a business that among other things is a Federal Aviation Administration-approved DC-8 overhaul and repair center, he is a seasoned hand on the Arizona aviation scene. "There was an outfit in Kingman—Aircraft Conversions I think it was—that worked like a factory line. It had huge cranes to lift blades. Off would go the wings and the tail. Workmen would torch off the landing gear. Finally they would roll what was left into a big furnace and in an hour this brand new airplane would be an ingot this size." He holds up his arms to measure a rectangle a man could get his arms around. "It just made me sick," he says.

Big fortunes were there for the taking. Hamilton remembers one scrap dealer who bought all the instruments from the doomed airplanes. "He got them at a buck apiece and sold them off at $35 a crack," he says. "Lightplane manufacturers bought some, and others went just through want ads." After all, they were brand new and top quality.

The arithmetic was simple, the profits staggering. One block of 4,000 airplanes went for $400,000. The buyer recovered his investment simply by draining the fuel on board and selling it. Then he peddled the aluminum ingot for 25 cents a pound.

One legendary strike-it-rich prospector was an Armenian immigrant who lived in Los Angeles. According to Hamilton, he couldn't read English but he had an uncanny ability of reading the minds of customers. "If I was thinking of paying $75 for some obscure part," he recalls with amazement, "that's exactly the price he would quote."

How did this penniless newcomer manage to acquire $35 million to leave to a California university at his death? Through such deals as paying four or five cents a pound for 300 new Wright R-2600-20 engines that powered the

A fence of Convair 240 propellers suggests a hybrid of air museum and sculpture garden (left).

Before airplanes are melted down, scrap dealers cannibalize still-functioning equipment for resale.

Approximately 70 percent of an airplane—mostly aluminum—can be recovered in ingot form.

likes of the Grumman TBF Avenger. When the Korean War came along, Hamilton says, the government bought the engines back for nearly $5 million, a profit for the scrap dealer of something like 20,000 percent.

By the time surplus aircraft storage was consolidated at Davis-Monthan, the legendary high rollers had come and gone. Still, Hamilton keeps an eye on the salvage business for his overhaul operations. Now in his mid-60s and with an adventuring life behind him that has included an attempt to sell airplanes in Cuba as Castro was slipping into power, the soft-spoken Hamilton looks like a benevolent grandfather who might have played right guard in college. He has a strong sentimental feeling for airplanes. "When I see axes taken to airplanes," he says, "it bothers me. I want to build airplanes, not break them up."

To drum up business for his overhaul operations, Hamilton makes it a habit to stay in touch with the scrap dealers. Thus on a typical southern Arizona blast-furnace day in mid-May, Hamilton is part of a crowd of 22 bidders at an Internal Revenue Service auction at the Evergreen Air Center at Marana, 25 miles northwest of Tucson.

On the IRS block are four McDonnell Douglas DC-8-51s and one Boeing 707 seized from a Park Avenue wheeler-dealer who had moved to Miami and got into tax trouble. Besides Hamilton, the only Tucson dealer present is Bob Gallaher. With his graying hair and perennial Tucson ruddiness, Gallaher looks like an elder statesman of scrap. A

Navigation instruments often pile up in a salvage yard as the dealer waits for a better market or the right customer.

trained metallurgist, he cut his teeth in the airplane salvage business in Phoenix. "I was in anti-aircraft in the service," Gallaher jokes, "so I was used to breaking them up." With $3,500 and a partner who knew how to get advances from metals buyers, he went into business in the mid-1950s at Litchfield Park in west Phoenix, where the Navy stored its aircraft. He migrated to Tucson when military storage was consolidated at Davis-Monthan.

His western straw hat, Levis, and silver belt buckle set Gallaher apart from the easterners clustered on the verandah of Evergreen's operations office. Soon everyone piles into pickups to drive to the airplanes parked across the runway. The bidders crowd under wings for shade and the real horse trading commences.

First up is the engineless 707. Right off Gallaher bids $25,000.

A New York dealer raises him.

In a few seconds of rapid-fire bidding the price is up to $40,000.

Gallaher surrenders and lets the New York dealer outbid him at $45,000.

"Oh sure," he says, "the buyer of that 707 can make money off parts." Seedy as the airplane looks from the outside, Gallaher allows that it is "okay inside . . . cockpit instruments all there, glass, seats, galleys." The price says something about the state of the used-aircraft economy: parts are scarcer these days and worth more than ingot.

Prices get steeper for the DC-8s. Gallaher stays in for one more hand. He starts the bidding at $25,000 for the first DC-8 on the block. Others raise their white bidder number cards and nod when the IRS rep asks who will go another $5,000. Soon the bidding gets too rich for an old salvage hand like Gallaher. "I was surprised at the prices," he says in his best poker voice.

The hottest item is a DC-8-51 with

two of four engines still on the wing and a heavier, more valuable version of the DC-8 main landing gear. Bidding starts at $50,000 and quickly runs up to $210,000 before the other players fold. The word among the losing bidders is that the winner has a deal in his pocket—Delta will buy the airplane from him for $250,000 and donate it to the Smithsonian.

Gallaher is probably a little more disappointed than he shows at not getting either the 707 or one of the DC-8s. "This is a romantic business in a way," he says. "When you buy an old airplane, you never know what you're going to get. If I had had good hindsight, I would have always bid more than I thought at the time."

If he had gotten an airplane at the auction, Gallaher's partner, Bob Hoover, would have done the melting down. Owner of Aviation Metals, Components, Engines & Planes, Inc., Hoover is a wiry and restless man whose aircraft yard could qualify as a museum itself. He and Gallaher were originally a team in the Phoenix days. "He was the kind of guy willing to do any job, running the furnace or the like," Gallaher says. "And then he had a good memory for part numbers." Later when Gallaher specialized in the precious metals recovered from aircraft electronics boards, he picked Hoover to run the aircraft side of his business.

Experience and lore are what it takes. "That's why the big scrap dealers in the east can't compete here," Hoover says. Except for scrap aluminum, the price of which is quoted in metal dealer newspapers, there may be nothing to base a bid on except experience and intuition. "I may have been selling an aircraft radio for $5,000," Hoover rattles off in his Type A fashion, "so I put in a bid on this basis and come to find out some other base has just sold 5,000 and they're now

Bob Gallaher used to specialize in precious metals from aircraft electronics boards. He now deals in industrial real estate.

going for $100 apiece." Metal markets don't stand still either. "It takes 90 days for the government to make an award," Hoover says, "and in that time the price for scrap aluminum may drop two or three cents a pound."

Transportation is another disadvantage to outsiders. Aircraft wing sections fill up a truck but only amount to 10,000 or 15,000 pounds in a trailer that needs to carry 40,000 to be cost-effective. As Gallaher puts it, "Aircraft structure largely surrounds air." It might take 10 truckloads to move a structure that will barely make a single load of ingot.

Increasingly rarer sales at Davis-Monthan keep business on the hush-hush among the four or five scrap dealers. Gallaher's description of one scrap dealer crony holds true for all of them. "Oh," Gallaher says, "he's a fellow who doesn't like to talk much. If he went to England and had an audience with the queen, he'd come back and just say, 'Yeah, I've been in London for a few days.' " The favorite joke that one local scrap dealer likes to tell about himself recently made the rounds in Tucson: "Ninety-eight percent of businessmen in this country are honest; the other two percent are scrap dealers."

It's a business where inventory must stay parked, returning nothing on an investment for years, its value taking on the cast of a trade secret. "Some of my helicopter parts have been around for 20 years," Hoover says, "and that can tie up a lot of capital." An intuitive grasp of residual values and timing is vital. Nine of a batch of 83 Navy P2Vs the government sold in 1986 are still parked next to Hoover's yard. At least a dozen were sold for fighting forest fires as water bombers. With patience, the rest will go, whole or piece by piece. Scrap works something like the retail clothing business, where the price is marked down until all the inventory goes. (And sometimes in reverse: "When something doesn't sell, I raise the price," says Hoover.)

Unfortunately for Tucson's salvage industry, what Davis-Monthan started, Davis-Monthan can end. Airplane salvage is slowly drying up in Tucson. At today's prices, too few military airplanes can be cast off lightly, so they tend to stay in operation longer. If they do come to Davis-Monthan, they are less likely to be sold for scrap. Instead of getting the former treatment of sealing tape over cracks and ducts, some go into large plastic bags that are easier to remove in a hurry. Certain Navy airplanes come in for storage with specifications that in the event of an emergency they be available in a matter of hours. Others are stored with no plans for withdrawal. Engines usually stay mounted and are run up every 45 days on the flyable aircraft or otherwise checked for deterioration every six months. Some come in for cannibalization, their parts rotated back into the military supply system instead of being sold for salvage.

The name change at Davis-Monthan tells the story. Before it was the Aerospace Maintenance and Regeneration Center, it was the Military Aircraft Storage and Disposition Center. Not only does that new title recognize the transition to preservation, but according to Jerry E. Mullins, the center's administrator, it also recognizes the government's own program for military sales to friendly countries.

The last sale out of Davis-Monthan included eight Boeing 707s plus miscellaneous parts for them and an assortment of helicopter bits and pieces. That was early in 1988. There used to be four or five sales a year; now it's surprising to see one. Gallaher thinks that the rest of the B-52s stored at Davis-Monthan will be the last batch of aircraft sold there, and that would happen only because arms treaties may necessitate their sale.

Dealing in surplus military aircraft is a doomed business, "but maybe not in my lifetime," says Hoover. He is slowly diversifying out of aircraft and into scrap iron from machine shops around Tucson. "About 50-50 aircraft and non-aircraft," is how he describes his business. Gallaher, too, has a lot of sidelines and now operates out of another enterprise: Tucson Aviation Center, which deals in industrial real estate.

But he maintains that the death of the salvage business is not imminent. There are a lot of airplanes still operated by the military that are all eventual candidates for disposal, he says. And there are a lot of commercial airliners—the geriatric transports so many worry about today—that are potential sources for parts tomorrow.

In the meantime scrap dealers worry

The aircraft in reclamation limbo are dwindling (left). Bob Hoover (right) has diversified; he now accepts scrap from machine shops.

about vanishing parts of another variety. There is "leakage," a corporate euphemism for shoplifting, to consider. It's not shoplifting for profit—although scrap aluminum prices have run up so much over the last couple of years that anything big and not nailed down may disappear. Rather, it's sightseers picking up souvenirs. "I had sold a batch of R-2800 engines about a month after a group visited my storage park," Hoover recalls. "When the time came for customer acceptance, all the data plates were missing. That cost me a lot of money." Needless to say, sightseers are considered a pain in the neck by scrap dealers, not only because of "leakage" but because they can get hurt around the yards, which are mazes of sharp and jagged sheet metal.

Another, stickier problem faces Tucson's scrap dealers. State, city, and county environmental and health agencies are concerned about military and manufacturer dumping of chemicals that may leach into precious desert groundwater. And the salvage yards accumulate blackish gray mounds of dross, the ashy residue left after aluminum is melted down. If the ash doesn't blow away, its lead and cadmium content can get into groundwater.

The military and the local governments are struggling with both the outrage of neighbors and health authorities. The potential impact of regulation on business is another consideration. Hoover, for one, says trucking the dross to hazardous-waste sites out of state could put him out of business. Whether or not it is hazardous to nearby residents, dross—and its disposal costs—will temper future bids at Davis-Monthan.

On a Davis-Monthan runway shimmering in the heat, olive-drab Tactical Air Command A-10s shoot touch-and-go landings, a reminder that airplanes do fly as well as sit. Across the road the salvage yards have the same haunted aura that pervades the abandoned gold and silver mines in the mountains around Tucson. Hoover just shakes his head over the way now-vintage aircraft were cast off. Not so many years ago Hoover got his hands on a batch of Navy PBY flying boats, all flyable. "I advertised them in trade magazines," he says, "and would you believe I didn't get one phone call?"

"I always try to buy the ones-of-a-kind," Gallaher says. "I just wish I had waited longer to sell them. I might pay $10,000 for one, sell it for $20,000, and think I hit a good lick. But look what they bring today. It's a shame I didn't have more hindsight, just to save a few P-51s or F4U Corsairs. I wouldn't be working today if I had."

The fortunes—and perhaps the future—of Tucson's salvage yards are pretty much summed up by Gallaher: "I've never lost money on an airplane," he says. "The only times I've lost money was when I *didn't* have airplanes."

Nearing the end of the salvage cycle, the broken wings of former warbirds will soon be melted down for reuse.

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JAMES SUGAR/BLACK STAR

A Permanent Presence:

Although the settlement of space is at least a decade away, NASA is making plans for the journey outward.

Second in a Series

This series of articles reports the steps being taken to make space a permanent address.

Life Beyond Gravity

A trip to Mars will take months. But the troubling effects of zero gravity take hold in only weeks.

by Jan Ziegler

"Your cheeks don't weigh anything and they don't keep your eyebrows down."

"My legs have gotten a bit thinner, my face has gotten a bit fatter."

"You go around with your shoulders hunched up because your arms don't hold your shoulders down."

"I called down and told my wife I was two inches taller."

The observations have a hallucinatory quality, but what was happening to the observers was real. When human beings venture into the weightlessness of space, startling things happen—and self-hunching shoulders are the least of them.

Before the age of space travel, the possibility that microgravity might pose a health risk was broadly dismissed by rocket scientist Wernher von Braun in the pages of *Collier's* magazine. But as experience in spaceflight accumulated, scientists observed that the zero-G environment was not benign, and that gravity was more than an amenity. Without it, the heart shrinks, bones thin, muscles weaken.

Now both the Soviet Union and the United States are seriously mulling over plans for manned missions to Mars—missions in which space travelers might have to endure long periods of weightlessness. Consequently, space physicians are facing an enormous realm of unknowns: Do the effects of weightlessness worsen over time? Are they ever permanent? Is gravity so essential that it will have to be simulated on long space missions?

Some say a propulsion system could be developed to get a craft to Mars in 60 to 90 days, a journey that could be comfortably endured without gravity. Even tried-and-true chemical propulsion could land us on the Red Planet in six to eight months, a tolerable amount of time to pass in weightlessness. But according to Ivan Bekey, chief systems engineer in NASA's Office of Exploration, if something were to go wrong on a chemically powered craft and the landing had to be scrapped, the mission would be converted to a "fly-around abort," which would take up to three years. And no one knows what would happen to the human body if it had to go that long without gravity.

It's a drunk's nightmare, but this spinning room at Brandeis University is a boon to researchers studying ways to simulate gravity. Rotating spaceships may one day keep astronauts rooted to the floor.

For many explorers, the first physical changes that occur in space include nausea, vomiting, disorientation, headaches, and irritability—"space sickness"—lasting up to several days. The cause of this syndrome is unclear. Physician Joe Kerwin, who traveled on Skylab 2, believes space sickness, like seasickness, results from a confusion of orientation cues. "When you are below deck on the *Queen Elizabeth*, your inner

JAMES SUGAR/BLACK STAR

Though it's not true gravity, centrifugal force could provide an acceptable substitute in space.

ear detects motion, but that picture on the wall is steady," he explained in Michael Collins' book *Liftoff.* "Ditto inside a spacecraft." However, recent centrifuge experiments by three European astronaut-scientists suggest that the symptoms of space sickness can appear when a person is accelerated on his back—the position astronauts assume during launchings.

During the first days of weightlessness, body fluid that gravity would normally pull toward the lower torso and legs shifts upward, swelling the space traveler's face, neck, and upper torso. In response to the perceived fluid overload, the output of diuretic hormones rises, resulting in increased urination, and the volume of plasma—the liquid portion of the blood—drops. Within 30 days, fluid balance is achieved.

With less blood in circulation, the heart shrinks slightly. Heartbeat is occasionally irregular. During long voyages lung capacity decreases, possibly because of the increased volume of fluid in the upper torso, or because the diaphragm drifts higher into the thorax.

Red blood cell production drops off a bit. No one is sure exactly why this happens, and while this "space anemia" is considered harmless, it could prove a serious complication for an astronaut who falls sick or is injured, especially on a lengthy mission. When new cells are produced, unusual variants—scalloped, squarish, mulberry-shaped, spherical—are often observed.

The number of killer and enhancer lymphocytes, white blood cells that attack invading organisms, also drops during long-term flight. Whether this is a response to weightlessness or to the stress of spaceflight is unclear. Other white blood cells—the neutrophils, responsible for gobbling up bacteria and other foreign matter—increase. Though it's still uncertain how these changes affect immunity, the Soviets are not taking any chances. When a flu epidemic swept Moscow in 1988, cosmonaut Yuri Romanenko, recently returned from a 10½-month space trip, was whisked off to a resort in the Caucasus mountains.

With no pressure on the vertebrae, an astronaut's spine expands, and consequently his height increases anywhere from half an inch to two inches. When Edward Gibson of the Skylab 4 crew told his wife about his new stature, she made plans to go out and buy a new pair of shoes. "We're equal in height when she's wearing high heels," he explains. "She's always wanted me to be taller." Unfortunately, back on Earth, gravity soon pulls erstwhile space travelers up short.

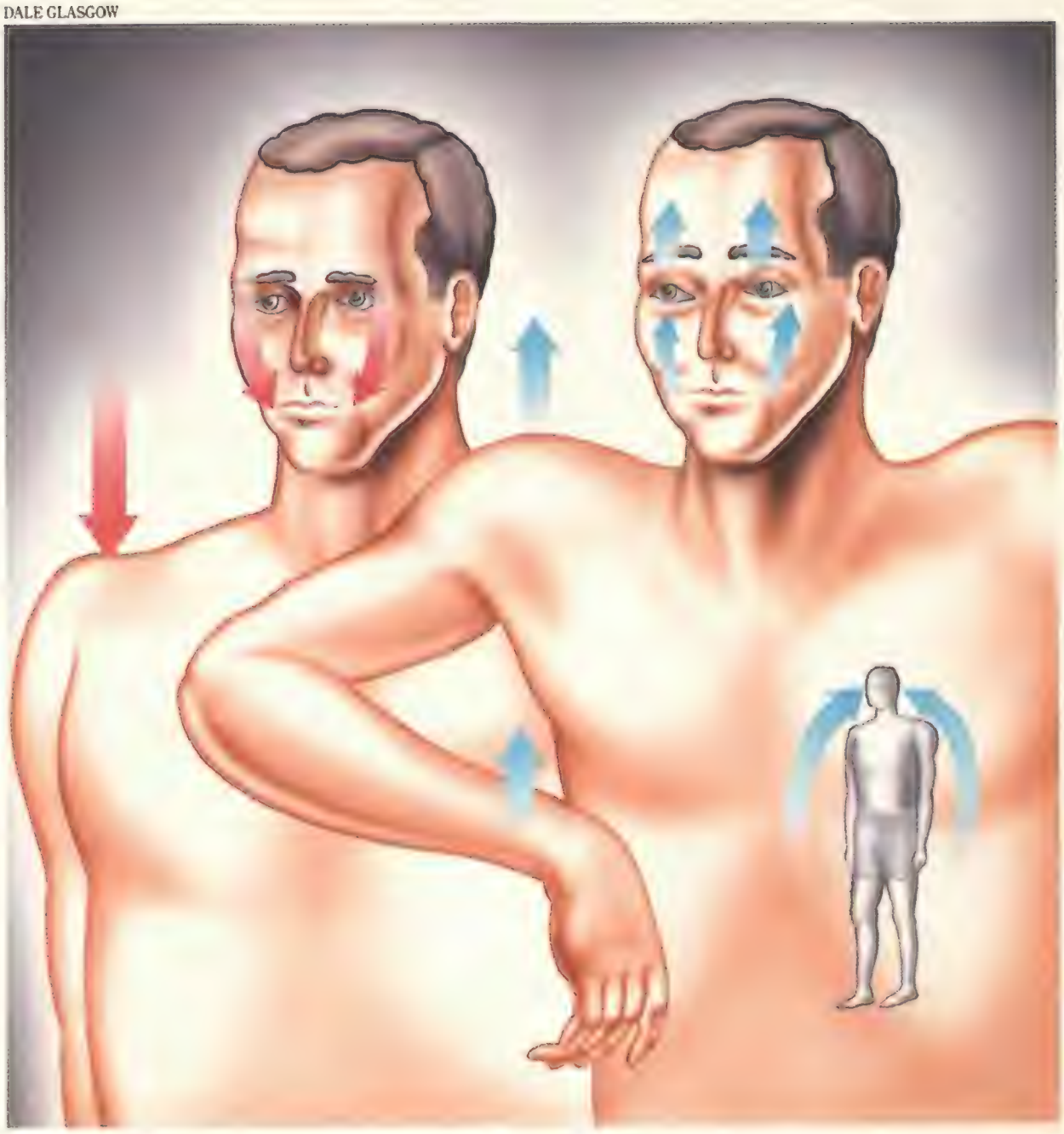
Space physicians are most concerned with how weightlessness affects bone and muscle. Bone relies on gravity to grow properly and maintain density, while muscles rely on it for resistance, which provides strength for everyday tasks. Without it, bones thin and grow more porous; muscles slacken and atrophy. Full recovery of muscle strength after space travel may take anywhere from several weeks to several months.

So far, bone loss appears to be the only permanent effect of prolonged weightlessness. Every month they remained in space, astronauts on the long Skylab missions lost 0.5 percent of their

body calcium, almost all of it from bone. While the loss has not hampered the space travelers' activities on Earth, some researchers are worried that bone loss would continue during longer missions. Most of the thinning occurs in the bones that on Earth bear the most weight, such as that in the heel. (One Skylab astronaut's heel showed an eight percent reduction in mineral content upon return to Earth.) The calcium lost from bone eventually makes its way to the urinary system, increasing the risk of kidney stones. In addition, when 40 to 60 percent of their mass is gone, bones fracture with alarming ease. That would be particularly dangerous in space, since studies on Earth have shown that fractures would heal in a disorganized fashion without the force of gravity. Bone loss in space may level off, according to Arnauld Nicogossian, NASA's director of life sciences, but more research is needed before mission planners can count on that.

The most comprehensive descriptions of the effects of weightlessness, still relied upon today, were collected during the 1970s Skylab missions, the longest of which kept astronauts in orbit for 84 days. But the Soviets have far more experience in life without gravity, having kept cosmonauts aloft for a year

DALE GLASGOW



Without gravity, body fluids rise, bloating space travelers' faces. Arms and shoulders drift upward as well.

ROGER RESSMEYER/STARLIGHT

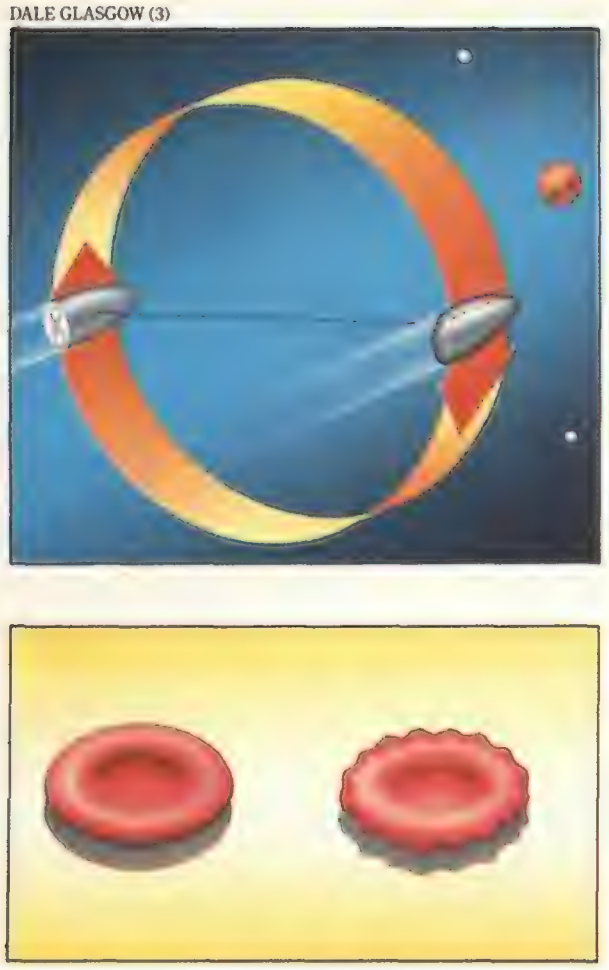
This apparatus causes blood to rush to the legs, simulating what happens when astronauts return to Earth.

during the 1987-88 Soyuz TM3 mission. Unfortunately, they have been slow to share their observations through traditional scientific channels and are not always explicit as to their methods of data collection. Anecdotal information has from time to time wafted out of Moscow, leaving Western researchers hungry for solid data.

It is known that the cosmonauts exercised diligently up to two and a half hours a day on the Soyuz TM3 mission to forestall bone and muscle deterioration. They also encased themselves in elasticized "penguin suits," which provide stress on muscles that normally work against gravity to hold us upright. Cosmonauts, like their U.S. counterparts, also work out on stationary bicycles. Toward the end of long missions they don negative-pressure suits, which move fluid out of the upper torso and provide the cardiovascular system with more exercise.

NASA bone physiologist Victoria

DALE GLASGOW (3)



One popular design for a rotating spaceship consists of two modules connected by a tether (top). Rotation may ward off some of zero G's side-effects, such as changes in the shape of red blood cells (middle) and elongation of the spinal column (bottom).

Garshnek points out that the Soviets precede each long flight with a bedrest study of equal duration. (On Earth, merely standing and moving about enables the muscles and bones to maintain strength by resisting gravity, so keeping volunteers continuously bedridden can approximate the effects of weightlessness.) How the studies were conducted isn't entirely clear, however.

One relatively inexpensive and time-honored remedy for medical problems is, of course, medication. Victor Schneider, director of the bone and mineral lab at Johnson Space Center in Houston, heads a team that is investigating pharmaceutical agents that may help ward off cosmic osteoporosis. Among the drugs under study is sodium fluoride, which promotes bone formation, and various diphosphonates, which inhibit resorption, the body's constant process of dissolving calcium from bones into the bloodstream while building new bone.

The problem with sodium fluoride is that it may cause bone development in the wrong areas, such as tendons or cartilage. Close monitoring would be required so that when this errant growth starts, astronauts could stop taking the drug. And diphosphonates halt the whole bone reformation process, so if an astronaut had a fracture, he would have to forgo the medication.

Another drug under investigation is calcitonin, which has already shown promise for osteoporosis on Earth. It also stops resorption and has been shown to increase bone density over two years.

Zero-G medications have their detractors. Astronaut Jack Lousma, for one, says that the idea of using drugs to ward off the deleterious effects of microgravity appeals to him not at all. "I'm just opposed to using medications of any sort unless it's absolutely required," he says. And Jeffrey Davis, chief of Johnson Space Center's medical operations branch, prefers solutions that more closely approximate normal physiological conditions. "I would lean more towards exercise or artificial gravity," he says.

On the subject of artificial gravity there appears to be agreement on two points. One is that any decision about its use is going to have to wait until animal and human studies are performed aboard the space station, scheduled for construction in the 1990s. And second, if artificial gravity is necessary, it will likely be provided by some sort of rotating arrangement.

When an object is rotated, or accelerated in a circular motion, it will be flung out from the center of rotation. This phenomenon—centrifugal force—could be exploited quite nicely in the design of a gravity-simulating spaceship. After all, if an amusement park ride can plaster you to your seat simply by rotating, a space vehicle that rotated (albeit at a less violent rate) could keep its occupants planted firmly on the floor.

Forty years ago, in what would come to be considered a landmark essay, Wernher von Braun proposed a doughnut-shaped space station that spun to simulate gravity (though he insisted that this feature was for the astronauts' convenience, not their health). Spinning doughnuts and similar designs certainly have acquired champions among the illustrators of science fiction novels and magazines. But according to Lou Livingston, a long-range flight specialist who recently retired from Johnson Space Center, the physics of acceleration dictate that such a craft, to provide a comfortably low 1 rpm rotation rate and a full 1 G of gravity, would have to be built on such a huge scale that it would only be useful as a station for hundreds of people. Instead, spaceship designers are thinking in terms of a barbell-shaped craft that can fling itself end over end through space, producing centrifugal force. The two main sections might include one module for the crew and another bearing propulsion systems and vehicles for ascent and descent to planet surfaces. The two sections could be connected by a long, flexible tether or a shorter, rigid truss.

According to the physics involved, the longer the connecting structure, the lower the rotation rate needed to produce the same G force. Thus, long tethers would be more appealing if it were determined that humans couldn't tolerate high rotation rates. But tethers have potential drawbacks. Says Livingston, "There are some peculiarities with spinning something up on a cable and

ROGER RESSMEYER/STARLIGHT

Muscles atrophy in space, so NASA is studying "passive exercise"—electrical muscle stimulation (above).

Astronauts in training ride a KC-135 that flies parabolic curves to simulate weightlessness for brief periods.

JAMES SUGAR/BLACK STAR

de-spinning it, which you have to do from time to time"—for mid-course corrections, for instance. "As long as the cable is spinning," he says, " 'gravity' keeps it under tension." But if the spinning were stopped, maneuvering could become a problem. Just as you can't very effectively push a piece of string, manipulating an ensemble with a limp tether could prove tricky.

A shorter, rigid truss poses its own limitations. As the distance between the crew compartment and the pivot point is shortened, the "gravity gradient" imposed on the traveler becomes more extreme—there would be much more gravity at his feet, in other words, than at his head.

Which craft we will ultimately board to get to Mars—tether, truss, doughnut, or some altogether different design—will depend in part on solving other unknowns. For instance: How much spinning would we need? How much could we stand? NASA has re-

cently begun a three-phase study to investigate these questions.

The first phase will look at people's ability to tolerate rotation, using rotating rooms at Brandeis University in Waltham, Massachusetts, the Navy research station in Pensacola, Florida, and other institutions. The rooms are of the type drunks have often visualized; they rotate about a central point, providing centrifugal force around the perimeter. Currently, the most conservative estimate of people's ability to tolerate rotation sets a 1 rpm limit, but preliminary rotating room studies suggest that 3 to 4 rpm may be possible.

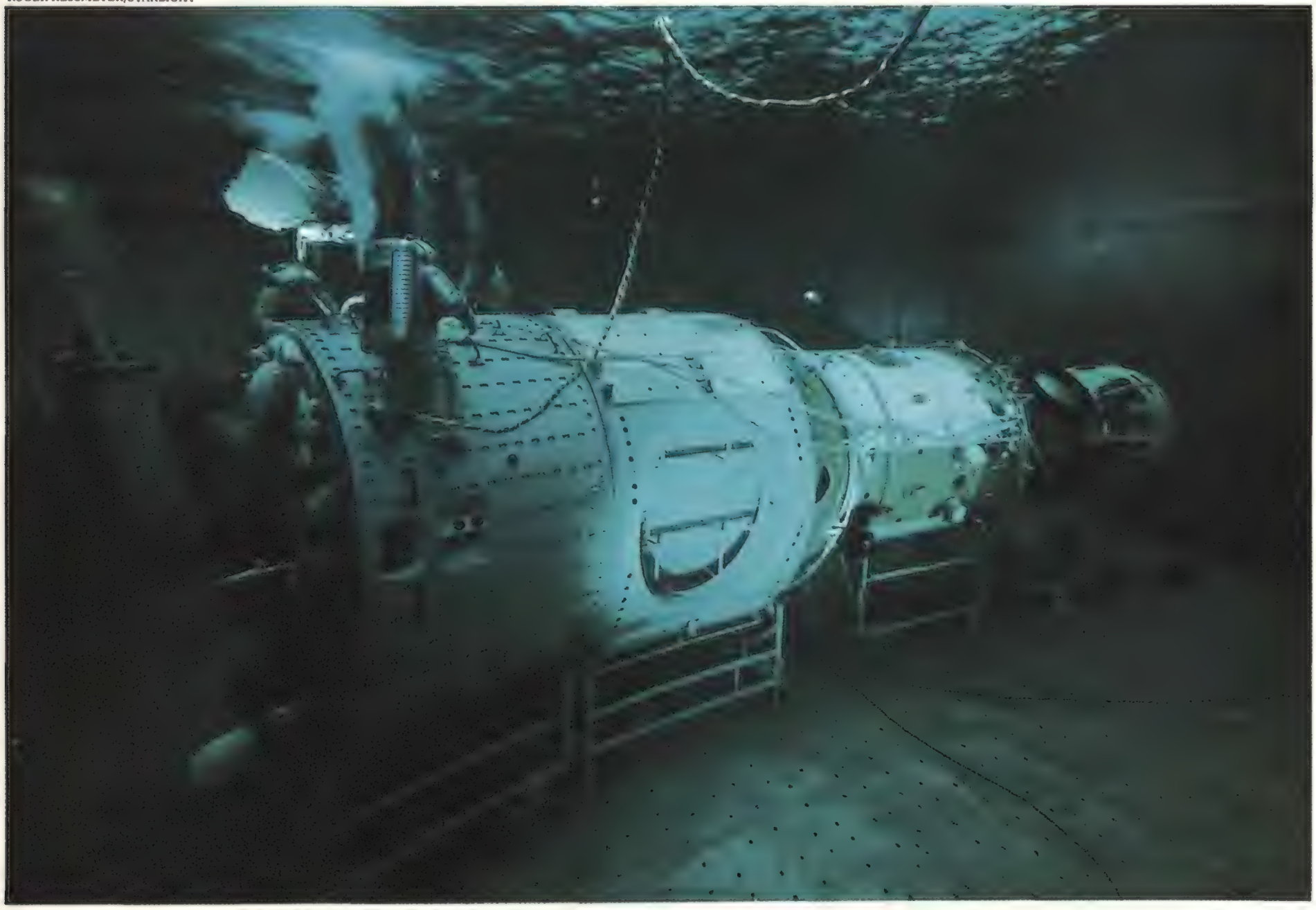
Rotation poses two problems. First there's the Coriolis effect—on a rotating surface, someone trying to walk a straight line along the radius will tend to stray to one side. The other problem involves the balance-maintaining vestibular section of the inner ear. When the head is turned, fluid in the vestibular duct follows the angle of the head and all is well with the world. If the owner of the head is on a rotating craft, the fluid shifts around and a peculiar feeling of moving on a different axis results. It's like sitting on a spinning piano stool; if you suddenly move your head, you'll likely feel sick and fall over. At a rotation rate of 1 rpm, these effects, if noticeable at all, are quite mild. They may also prove bearable at higher rates.

The second phase of NASA's study will start to determine whether artificial gravity must be imposed continuously or whether it can be intermittently administered. Could a craft be spun, say, overnight and kept stationary the rest of the time? It's a possibility. But another possibility would be to stow a device aboard that astronauts could slip into from time to time to get the appropriate G-dose.

Graduate student Peter Diamandis has come up with an idea for such a device, which is now being tested at Massachusetts Institute of Technology. The device, a rotating bed in which the sleeper's head is positioned at the pivot point, provides the equivalent of 1 G at the sleeper's feet. The idea is that demineralization may be staved off by applying a gravity-like force along the longitudinal axis of the bone. Though the bed rotates at the torturous-sounding rate of 23 rpm, the sleeper is well strapped in, and he is mercifully supplied with a blindfold to prevent visual disorientation.

"The first question was: Was it possible for anyone to sleep on this?" says Laurence Young, director of MIT's Man-Vehicle Laboratory. "The answer is yes." A student did it. Another volunteer, Chuck Rudiger, a Lockheed centrifuge program manager, rode it last summer, though he didn't try to sleep on it.

ROGER RESSMEYER/STARLIGHT



An underwater tank gives training cosmonauts an idea of what it takes to work in microgravity.

"It was comfortable," he says. "That was the surprise. I suppose you could get used to it if you were going to sleep on it every night."

Rudiger's company, teamed with Honeywell and Boeing, is competing with McDonnell Douglas to build an eight-foot centrifuge that will be installed on the space station to test artificial gravity concepts using animals and plants.

Relatively low-rent experiments are also planned: at Baylor Medical School in Houston and NASA's Ames Research Center at Moffett Field in California, old-fashioned bedrest studies will investigate the potential of intermittent gravity-dosing. For various periods of time, paid volunteers will lie in beds tilted at a six-degree angle to pool fluid in the upper torso and depressurize the vertebrae, simulating the effects of microgravity. Medical staff will keep watch and take blood and tissue samples. Says Russell Nelson, a San Jose-based graphic artist who regularly volunteers for bedrest studies, "After a while it gets pretty comfortable and you can see yourself going for longer periods of time."

But bone and muscle biopsies are painful, and getting up can be unpleasant. Volunteers are brought vertical in stages: first they're propped up with pillows, then they sit up, and finally they stand up and walk around with help. "You feel kind of weak," Nelson says. "You get a little anxiety. You might be a little light-headed and a little dizzy. I passed out one year. The worst of it is over in half an hour." (Jack Lousma would probably sympathize. After landing at sea and being picked up by ship, the veteran of the 59-day Skylab 3 mission remembers feeling "very heavy for 24 hours. I felt that if I rolled off the bunk where I was lying, I would go right through the deck and the bottom of the ship.")

The third phase of NASA's study will determine the level of gravity that would be necessary if artificial gravity has to be provided. Says Frank Sulzman, chief of NASA's space medicine and biology branch, "Maybe eight- or nine-tenths of a G are enough." And if we could get by with less gravity, we may be able to get by with less complex spacecraft.

NASA

The facial and posture changes Mary Cleave experienced aboard the shuttle in 1985 are typical of life without gravity.

There are a few wild cards in the zero-G game. For one thing, there's every government agency's perpetual problem: funding. Two studies, one produced several years ago by NASA's Marshall Space Flight Center in Huntsville, Alabama, and one produced in 1989 by Boeing, showed that a craft providing a full 1 G for 24 hours a day would weigh 20 to 25 percent more than a conventional one (though Ivan Bekey says that subsequent analysis suggests a more modest five to 15 percent increase). The space agency is now working out what that added load would come to in dollars and cents.

Beyond the problem of simulating gravity in flight, what will happen once people get to Mars and live for a time in its .38 G gravity? What will happen on an intermediate base on the moon, where the gravity is not even half that? Says Barney Roberts, manager of planet surface systems at Johnson, "We have adopted the assumption we will not need any additional gravity either on the lunar base or the base on Mars. We don't know if it's true." The scientists researching artificial gravity, he says, told his unit, "go ahead and design your systems and we'll let you know in 10 years" whether they're adequate.

And finally, though the concept of artificial gravity has its fans, some, including more than a few astronauts, regard it with distaste. At a 1984 symposium in Moscow, the question "How many think a Mars trip could be done in zero G?" was posed to two groups: technical people and those who had actually ventured into space (both Soviet and American). According to Skylab 3 crew member Owen Garriott, the majority of the technical people declared that artificial gravity would be necessary. When the astronauts and cosmonauts were polled, only two out of more than 40 agreed.

"I enjoyed zero gravity," protests Ed Gibson. He found it a natural environment to which the body can adapt and which is ideal for space activities such as moving equipment. Says Jack Lousma, "It was just as instinctive after a few days to float as it was on Earth to walk. We felt in tip-top daily condition after having adapted. The question is: When you get to the end of the line, what's going to happen there?"

NASM

Keepers of the Flame

Engineers say scramjets will slash the price of space travel. But first they have to break the budget barrier.

by T.A. Heppenheimer

The difficulties the Air Force has encountered over the past three years in identifying an Aerospaceplane program have sprung from the facts that the requirement for a fully recoverable space launcher is at present only vaguely established, that today's state of the art is inadequate to support any real hardware development, and the cost of any such undertaking will be extremely large.

NASA

This is not a statement issued by the Pentagon last spring explaining why the Air Force wanted to drop the National Aerospace Plane from its 1990 budget request. It is part of a report issued for the Air Force by its science advisory board in 1963. The aerospace plane has hit hard times before.

In the heady optimism of the 1950s, propulsion experts thought they were closing in on a scramjet, an engine that could power an aircraft from runway to orbit. "Here comes the Flying Stovepipe," announced a 1965 *Time* story alluding to the engine's deceptively simple design. Like the ramjet, its slower predecessor ("slow" being about Mach 5), the scramjet has no turbine or compressor. It is a mere duct, carefully shaped to compress and control the air ramming into it at high speed. Because the scramjet can use the oxygen in the air as an agent in combustion, it could drive a craft to orbit without the towering silo of oxidizer required by a rocket.

NASA historian James Hansen has made the point that the work on space planes between 1952 and 1957 was conducted "*after* aeronautical experts first became convinced that space flight was both a real and imminent possibility, but *before* the Sputnik crisis incited the country's rush to get the first man in space, *no matter how it had to be done . . .*" (his emphasis). It

A 1974 wind tunnel test on a small model shows how scramjets would operate within the shock wave formed at Mach 6. Old testing techniques, like piggybacking ramjets on a P-51 (left), won't work for scramjets.

was eventually done with a rocket, of course, not because the rocket is necessarily the best way into space but because it could get there first. It is still the only way, despite the fact that in today's rocket-powered shuttle system, two-thirds of the total weight is contributed by the oxidizer. The scramjet believers were racing to reduce the weight, and therefore the cost, of transportation to space, before the budget crisis in the mid-1960s yanked their funding out from under them.

"We laid off two-thirds of our people in one day," recalls Art Thomas, retired vice president of the Marquardt Company, a firm near Los Angeles that had invested heavily in hypersonics research. Thomas began his career at Marquardt in 1950, "at the beginning of everything," as he puts it. "In those days you could get money for any good idea." His first project was the propulsion system for the Bomarc missile, the first to use ramjets.

There is still a trace of surprise in Thomas' voice when he remembers how the 1960s budget crunch affected Marquardt. For Air Force-supported hypersonics research in 1969, "we were expecting funding at $100 million," he says. "It went to zero. I was chief engineer and assistant general manager, and *I* got laid off."

Thomas and other engineers found it hard to accept that the technologies they had worked on and believed in wouldn't be built. Some of the senior members of the community campaigned against the budget cuts. Among them was Antonio Ferri, considered the father of hypersonic propulsion in this country. "He was one of the few voices who spoke out loudly," says Thomas. "He told them, 'You're going to be sorry because these are things you'll need. You can't fund only the category of things that the military needs right away.' "

The reversal of fortunes must have been particularly ironic for Ferri, since he had been brought to the United States from Italy during World War II for his expertise in supersonic aerodynamics. He had been the director of one of Europe's most advanced wind tunnels, a supersonic facility near Rome. In 1944, the Office of Strategic Services, the forerunner of the CIA, brought him to an aeronautical research center in Langley, Virginia, where he lectured to enthralled scientists about supersonic flight. Had the scramjet overtaken the rocket, as many believed it would, Ferri's name would now be as familiar as Wernher von Braun's. As it happened, Ferri's visions, like those of Eugen Sänger and other scientists who believed in transatmospheric space planes, have never been realized.

Ferri stayed at the Langley research center but continued to lecture to other groups of scientists and engineers around the United States. After several years, he collected his lecture notes and published the first textbook in the field. He joined Brooklyn Polytechnic Institute, where he began an aerodynamics research lab in 1951—at the beginning of everything. Soon he was consulting for major aerospace firms, drawing in so many contracts that his graduate students couldn't handle the work. So with financing from the Rockefellers, Ferri set up a company, General Applied Science Laboratories (GASL), which quickly grew into one of the nation's leading centers for research in high-speed flight.

One of Ferri's sponsors during this period was Alexander Kartveli, chief engineer at Republic Aviation in Farmingdale, New York. Kartveli, a Soviet émigré whose credits include the World War II P-47 and the Air Force F-84 and F-105, was a major figure in aviation at the time, an intellectual who was renowned for bold design and respected for encouraging innovation from the engineers who worked for him. He hired Ferri to design propulsion systems for the proposed XF-103, an interceptor that Republic was developing for the Air Force. It was designed to reach speeds of 2,500 mph with ramjet engines. The Air Force decided to cancel the XF-103 program without building even a prototype aircraft, but the collaboration between Ferri and Kartveli left a mark on the aerospace industry nonetheless.

Shortly after the XF-103 program ended, Kartveli began to urge his colleagues and others in the industry to dream of "the ultimate airplane," an ascent-to-orbit craft embodying Ferri's theory that there was no natural limit to aircraft speed or performance.

But in 1957 propulsion scientists were running into two stubborn and familiar limits to speed: time and temperature. Overcoming one meant facing the other.

The X-7 experimental unmanned aircraft had flown 60 times by 1957, setting speed records that stand today. With a ramjet developed by Roy Marquardt and his company's engineers, the X-7 flew across the New Mexico desert at 2,881 mph, faster than any jet has ever flown and about as fast as a ramjet can go. At much faster speeds, ramjets get too hot.

COURTESY LOUIS NUCCI

Men in power: President John Kennedy greets Antonio Ferri at a ceremony honoring aerodynamicist Theodore von Kármán (center).

The high speeds and increased range afforded by ramjets made them the choice for the XF-103, a proposed Mach 3 interceptor (above), and the Bomarc missile (right).

NASM


U.S AIR FORCE

NASM

The air that rams into the engine at supersonic speed passes through a number of shock waves until it has slowed to subsonic velocity. In subsonic airflow, fuel is burned more efficiently; however, in the process of slowing down, energy changes form. When the air loses speed, it gains heat. As a result, at more than about 4,000 mph, the internal temperature of the engine becomes so high that the combustion products dissociate. The dissociation process itself consumes energy, cools the exhaust, and thereby reduces the engine's thrust.

Engineers can overcome high temperature by maintaining supersonic airflow. But then they reenter the race against time. In supersonic flow, there is only a millisecond in which to get the air and fuel mixed for combustion and a new world of difficulties involved in maintaining combustion. (Imagine holding a lighted match outside a moving car.) A number of groups across the country, including GASL and Marquardt, were juggling temperature and time in 1957 when William Avery, a physical chemist at the applied physics lab of Johns Hopkins University, proceeded with a project to obtain speeds better than Mach 4 from Navy missiles.

Avery brought chemical engineer Gordon Dugger and mechanical engineer Frederick Billig to the lab for the project. A good salesman as well as a good scientist, Avery always kept in mind not only the success of a project but also its presentation to the lab's potential funding sources. "We need a snappy name," he told Billig. So Billig sat down with a set of lettered tiles, arranged and rearranged them to try out several ana-

grams, and came up with SCRAM, for supersonic combustion ram missile. The scramjet was born.

There is still a dispute over who built the first scramjet. In 1959 Billig ignited a small model scramjet in a wind tunnel at Mach 5, using a chemical that spontaneously burns on contact with air. Shortly thereafter, Ferri demonstrated the ignition of hydrogen in the GASL wind tunnel at Mach 6. Both groups were invigorated by their achievements. In 1961 Avery sent NASA a proposal for a Mach 7 scramjet aircraft that he claimed could be flying in ten years. GASL, Marquardt, and Republic Aviation started basic research on what came to be called Aerospaceplane, with support from Weldon Worth, the chief scientist at Wright-Patterson Air Force Base. Marquardt and GASL merged, with Ferri as a vice president.

If the scramjet had been able to harness the energy of the teams who were working on it during this period, an aerospace plane would be flying today. Art Thomas says, "Ferri would swing by and would give me and my staff about four times more work than we could accomplish. I complained about this to one of Ferri's colleagues, who replied, 'He knows that. He only expects you to accomplish one-fourth of what he gives you. Your problem is to figure out which one-fourth does he want.' "

The one-fourth that Thomas selected resulted in an inlet test in 1965 that gave encouraging results at Mach 10. Earth's orbital velocity is Mach 25. They were nearly halfway there. Later, a Marquardt team led by Ken Woodgrift got a full-scale engine demonstrating useful thrust at Mach 5.6.

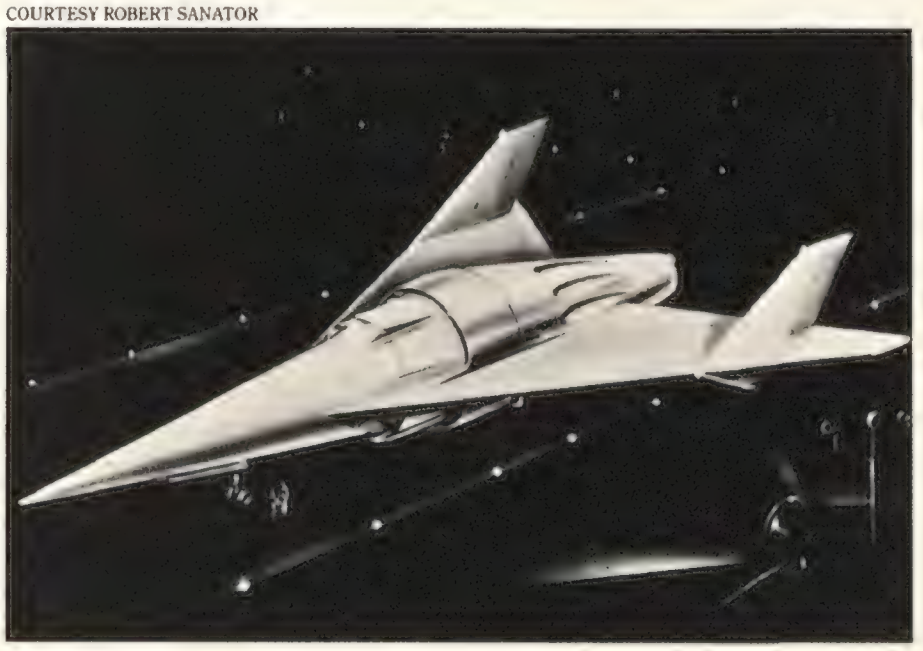
Meanwhile, the aircraft emerging at Republic looked very odd. With stubby wings and a conical nose, it was to be encircled by its cylindrical engine. (Integrating engine and vehicle surfaces is today part of the National Aerospace Plane design.)

Robert Sanator, one of Kartveli's managers at Republic at the time, says it was one of the most exciting periods of his life. "This one had everything," he says. "There wasn't a single thing in it that was off-the-shelf. Whatever problem there was in aerospace—propulsion, materials, cooling, aerodynamics—Aerospaceplane had it all."

Aerospaceplane would run into the final problem—money—by the middle of the decade, but even before then the scramjet faced big technological hurdles. No wind tunnels existed or were planned to test the engines at the extremely high speeds at which scramjets are particularly efficient. And in the era before supercomputers, the small capacity for data analysis was a severe limitation in an area of research that is so dependent on mathematical calculation. Fred Billig describes pounding away at a Friden adding machine, spending weeks on computations that today are done in seconds.

In 1966, while the Air Force was withdrawing from hypersonic research, NASA finally gave the scramjet a chance to fly.

COURTESY ROBERT SANATOR



In Republic Aviation's 1963 design for an aerospace plane, scramjet engines encircled the fuselage (above).

The Lockheed X-7 ramjet test vehicle, drop-launched from a B-29 in the 1950s, set speed records that still stand.

NASA (2)

How to Go With the Supersonic Flow

No ground facilities are capable of creating the combination of velocities, temperatures, and pressures necessary to simulate flight conditions between speeds of Mach 8 and 25. But since the 1950s, scientists have been building test components and small models to collect data on supersonic combustion. In 1976 NASA researchers experimented with the inlet at left, its cowl removed to show the wedges that channel and compress the air. Small ports, visible at the mouth of the inlet, measure static pressure at various points in the flow. Results of tests at Mach 4 and 7 helped determine optimum wedge shapes for engine sidewalls and fuel struts, the parts of the scramjet that perform the same function as a turbojet's compressor.

Because the most critical problem in supersonic combustion is the mixing of air and fuel, fuel struts, inside the rectangular test engine shown below, are placed where the air is densest to give the best chance of mixing. The actual point at which the microsecond fuel burn occurs moves aft as airflow velocity increases. During tests, the back of the engine was connected to a 100-inch vacuum sphere to simulate low-pressure conditions at high altitudes.

The NASA Langley Research Center, where Ferri had worked during the 1940s, awarded Garrett AiResearch a contract to build the Hypersonic Research Engine, a small experimental scramjet, and test fly it on the X-15 rocket plane at speeds up to Mach 8.

The HRE was designed by a team led by Tony duPont, an inventor who had come to Garrett after managing Aerospaceplane studies at Douglas Aircraft. But by the time the HRE contract was awarded in mid-1966, the Air Force had ended its support of the X-15. That left the aircraft entirely in NASA's hands, and NASA, with budget problems of its own, declined to keep the X-15 flying. The HRE was redirected into ground testing, and duPont went out on his own.

Like Ferri, Thomas, Billig, and other scientists and engineers who had gambled their careers on the promise of the scramjet, duPont now faced a kind of professional limbo. "We did whatever we could," duPont says. "Some years I could bring in consulting income."

Ferri returned to teaching. In the spring of 1967 he took an endowed professorship at New York University and proceeded to build a supersonic research lab in the Bronx. But the lab was much smaller than GASL; John Erdos, one of Ferri's students who is now vice president of GASL, says, "He felt he was only half a researcher. His love was to do experiments."

Thomas looked for work in ramjet-powered missiles. "I went all over the country," he says. "Everything in ramjet missiles had collapsed." Solid-fuel rockets, such as Phoenix and Sparrow, had taken their place. Thomas found a position with McDonnell Douglas in St. Louis, where he worked on turbojets. He later became a deputy assistant secretary of the Army at the Pentagon, where he was the civilian head of research and development for tactical missiles. "I went on a campaign to educate the world," he says. Thomas argued so persistently against rocket-powered missiles that he acquired the nickname Roger Ramjet. When Jimmy Carter moved into the White House, Thomas moved back to Marquardt.

Billig continued to focus on basic engineering studies—fuel mixing, combustion, and inlet design. At times he had only enough money to support a handful of people in his group, but the Navy continued modest funding.

The Langley research center, which had become a NASA center, continued to test the HRE in wind tunnels. By the early 1970s even this work was fading, but supporters of scramjets at Langley were able to get low-level funding for a new set of experimental engines. The resulting contracts brought Ferri back to GASL and GASL back to scramjets.

Marquardt had been bought in 1969 by a Tulsa-based truck manufacturer, and GASL had stayed alive by doing studies on whatever would bring in money—pollution, coal combustion, high-speed trains, low-drag wings. With the commitment from Langley, the original founders were able to buy the company back from the truck manufacturer, and Ferri came back as its president in 1972.

Tony duPont invented a scramjet that could take off from the ground under its own power with a clever arrangement of rockets, heat exchangers, and fuel injectors to provide the initial boost. He patented his design and set up his own consulting firm, duPont Aerospace, hoping to win Air Force or NASA support for its development, but by the late 1970s he decided to run tests on his own. He built a small model of his boost-at-takeoff apparatus, using wood and plexiglass, and tested it in the backyard of a friend's house in Santa Ana, California, with an air compressor that he bought at Sears. He arranged for GASL to test his engine design if he ever got funding.

NASA

Computer-simulated airflows show the temperatures a space plane must withstand. Blue is hottest: 1,100° F.

By this time, duPont was becoming a familiar face at the Pentagon's Defense Advanced Research Projects Agency. "Every year, I would come back to see some key people in NASA, the Air Force, Congress," he recalls. "Every year I'd make some kind of concerted effort."

During one such effort, he spoke to DARPA project manager Robert Williams, who, like Art Thomas, was trying to interest the Navy in ramjet-powered surface-to-air missiles (see "The Hypersonic World of Robert Williams," February/March 1988). Williams had been consulting Fred Billig about advanced propulsion. The people and ideas began to come together for what in 1985 became the National Aerospace Plane, a $3.3 billion program.

The Gramm-Rudman Act of 1985 and relentless technical difficulties have once again made the future uncertain for scramjets. The NASP program managers ambitiously set 1990 as the deadline for deciding whether the technology had matured enough to enable the building of an experimental aircraft. That decision has now been deferred to 1993. But for the believers who have maintained their conviction through the perennial budget traumas and daunting technological challenges of the past 30 years, it may not be so difficult to hold on for a few more. "I am 100 percent convinced," Art Thomas said recently, "that the only hope for extremely large savings in launch systems is the scramjet."

Skyward: Why Flyers Fly *by Russell Munson. Howell Press, 1989. 208 pp., color photos, $45 (hardbound).*

With all the aircraft photographs in *Skyward: Why Flyers Fly,* a more appropriate subtitle might be *What Flyers Fly.* Russell Munson has worked for *Flying* magazine for some 20 years, and some of the photos in *Skyward* that originally accompanied the magazine's pilot reports are rather sterile. But the majority have Munson's magic touch, displaying the graphic skills of a man in love with airplanes and the perspective they afford.

Once you get past Richard Bach's introduction ("My friend . . . is a mystical cosmic carpenter"), you will quickly fall under the spell of Munson's photographs, which capture unique aspects of dozens of airplanes: the dovetailed joints of a Stinson Detroiter control wheel, the symmetry of a banked Beechcraft Staggerwing, a crop duster blurred over telephone wires, the nearly opaque windshield of a de Havilland Beaver landing on a lake in the rain, the lavender light on the leading edge of a wing glowing like neon, a neatly dissected B-52 at Davis-Monthan Air Force Base. Munson is probably the only photographer who can make even the gawky, barrel-chested Polish Wilga bushplane look good.

Scattered among the photos are interviews with a cross-section of pilots: a Concorde captain, an art director, a P-51 owner, a corporation president who started flying at age 49 and now, at 71, flies her own Cessna Citation. Though some fly for a living or to get somewhere fast, all say that what hooked them was the view, the solitude, the challenge, and the beauty of the various machines they fly. A book editor admits that when inclement weather prevents him from flying his Cessna 172, "I'll go out sometimes and just sit in the damned thing."

One of Munson's own stories describes the thrill and challenge of logging 13½ hours in a DC-3 to get type-rated in the classic airliner just for the honor of it (on DC-3 brakes: "It's like the first time you stomped on the power brakes of a '55 Chrysler and launched your Mom into the glove compartment"). And a piece on flying ultralights at Manteo, North Carolina, an experience that so enraptured Munson he ran out of fuel several hundred feet over the airport, is highlighted by a stunning photograph of a pair of blue-jeaned and booted legs suspended 1,000 feet over the coast. If you tilt your head back and squint a bit, it's easy to imagine they're your boots perched on the spoiler pedals of an Eipper-Formance. Whether you enjoy the resulting sensation is another matter.

—Patricia Trenner is the departments editor of Air & Space/Smithsonian.

The Minotaur *by Stephen Coonts. Doubleday, 1989. 436 pp., $19.95 (hardbound).*

Like the minotaur of Greek legend, *The Minotaur* by Stephen Coonts is a hybrid creation with a large dose of bull. Unaccountably, Coonts has strayed far from the action-packed formula that made *Flight of the Intruder* and *Final Flight* such models of the techno-thriller; *The Minotaur* moves at a sluggish pace, and much of the action is played out in the labyrinthine corridors and conference rooms of the Pentagon. The result is an odd blend—part espionage novel, part discourse on weapons procurement—that suggests a new genre: call it the bureaucro-thriller.

The book does have an intriguing premise. The time is the very near future, and the U.S. Navy is looking for a stealthy fighter-bomber to replace its aging A-6 Intruder. The best candidate is the top-secret Advanced Tactical Aircraft, also known as the ATA or A-12, which Vice Admiral Tyler Henry describes in perfectly rendered Pentagonese as "an all-weather, go-anywhere anytime carrier-based attack plane that will equal or exceed the A-6 in range, speed, and payload and carry advanced sensors that will make the A-6 look blind as a cornfield scarecrow."

Indeed, the ATA threatens to make cornfield scarecrows of every Soviet radar operator from Vyborg to Vladivostok. It boasts a radar suppressor dubbed "Athena" that will neutralize hostile radar signals and allow the A-12 to penetrate enemy airspace undetected. The Navy is understandably anxious to find someone who can oversee its production without tipping off the Minotaur, a deeply burrowed but high-ranking Pentagon mole who is feeding the Soviets a steady diet of U.S. state secrets.

Only one man is equal to the task, but unfortunately Coonts killed him off in his previous novel, *Final Flight.* Or did he? Witness the resurrection of Navy captain Jake Grafton, hailed by Admiral Henry as a "shit-hot attack pilot with a ton of smarts and a gilt-edge reputation who can waltz a little project through the minefields."

As program manager for the ATA, Jake proves to be a quite nimble waltz partner. In the Pentagon and on Capitol Hill, he must defend his choice of a female test pilot, Lieutenant Rita Moravia, while concealing her involvement with the ATA's bombardier-navigator, Lieutenant Toad Tarkington. There's also the challenge of convincing a gadget-leery Congress to shell out $5 billion for the ATA's development and another $17 billion for its production.

Add to these story elements an FBI counterintelligence agent who may be in league with the KGB and it would appear that Coonts has assembled all the ingredients necessary for a thoroughly engaging tale. Nonetheless, the final mix falls short. One obvious handicap is the book's peacetime setting: Coonts must wring what drama he can from such incidents as a midair collision between the A-12 and a bird. Coonts also seems overly protective of the Minotaur's identity. He keeps his protagonist in the dark for so long that when—on page 383—Jake Grafton muses, "Something is *supposed* to happen . . . and it hasn't happened yet," readers may well mutter, "Amen!"

As a treatise on the benefits and perils of military "techno-junk" *The Minotaur* is an untrammeled success. As a work of fiction,

however, it matches the Minotaur's own description of Athena: "Sounds like something Tom Clancy dreamed up after he had a bad pizza."

—Allan Fallow is an editor at Time-Life Books.

***DEFCON One** by Joe Weber. Presidio Press, 1989. 336 pp., $18.95 (hardbound).*

DEFCON One, titled after the term for the military's highest state of pre-war readiness, starts off with a plausible scenario. Mikhail Gorbachev's reforms have stalled. A circle of old hard-liners, determined to reverse the Soviet Union's rapidly declining state of affairs, plots his assassination and takes control. Victor Zhilinkhov, the new secretary general, then puts a daring plan in motion: he will push the United States to the brink of war, then relent. When the Americans have relaxed their military posture, the Soviets will launch a nuclear first strike.

As Soviet forces step up the pressure, a mole deep in the Kremlin learns of Zhilinkhov's true plans and informs his CIA contact. The race is then on as the two agents, hounded by the KGB, desperately try to warn Washington.

The author is a former Marine Corps pilot with a firm grasp of the aircraft and weapon systems he writes about, although he often walks the reader through each encounter in excruciating detail. He is at his best when describing the aerial action that takes place as the Soviets turn up the heat. Unfortunately, Weber's dialogue is often reminiscent of Sergeant Slaughter of comic book fame. Everyone in uniform is a hero, and pilots seem to converse almost exclusively in macho banter. In one typical example, an S-70 pilot peeling off to hold back a horde of Soviet armed "helos" and meet certain death radios his buddy: "You owe me a beer!"

Techno-thrillers are being turned out in ever-increasing numbers, and this book illustrates some of the worst traits of the genre. War is not hell, it's an exhilarating game of cowboys and Indians played by cardboard characters who don't know the word "fear." It's a far cry from the stark realism of such World War I memoirs as Robert Graves' *Goodbye to All That.*

Military fiction seems to run in cycles. The realism of the Vietnam war era seems to have given way to a tradition in which the horrors of combat are dimmed and technology reigns supreme.

—John Morrocco is senior military editor of Aviation Week & Space Technology.

Credits

The Battle of Los Angeles. A retired CBS broadcasting executive, Tom Swafford now lives and writes in Asheville, North Carolina.

The Big Chiller. Edwards Park is a frequent contributor to *Air & Space/ Smithsonian.*

Flying at the Bottom of the World. Charlotte Evans spent three months in the Antarctic under the auspices of the National Science Foundation where she wrote a series of articles for the *New York Times.*

Further reading: *South Light: A Journey to the Last Continent,* Michael Parfit, Macmillan, 1985.

Goodbye, Voyager. Mark Washburn is the author of *Mars at Last,* a book about the Viking missions, and *Distant Encounters,* an account of the Voyagers' findings at Jupiter and Saturn. He lives in Massachusetts.

Further reading: *Imaging Saturn: The Voyager Flights to Saturn,* Henry Cooper Jr., Holt, Rinehart and Winston, 1982.

Voyage to Jupiter, David Morrison and Jane Samz, NASA, 1983.

The Autogiro and Its Legacy. Richard Aellen is a novelist, travel writer, and flight instructor. His novel *Crux* (Donald I. Fine, Inc.) came out last month.

The Cosmos According to McCall. Karen Jensen is an associate editor at *Air & Space/Smithsonian.*

Further reading: *Vision of the Future: The Art of Robert McCall,* Ben Bova, Harry N. Abrams, Inc., 1982.

The Bone Pickers. William H. Gregory is a former editor of *Aviation Week & Space Technology* and the author of *The Defense Procurement Mess* (Lexington Books, 1989).

Life Beyond Gravity. Jan Ziegler is a Washington, D.C.-based journalist who has written for *American Health, Omni,* and the *National Geographic.*

Further reading: *Space Physiology and Medicine* (2nd ed.), edited by A. Nicogossian, C.L. Huntoon, and S.L. Pool, Lea & Febiger, 1989.

Keepers of the Flame. T.A. Heppenheimer is the author of *The National Aerospace Plane* (Pasha, 1987) as well as articles for *Omni* and *High Technology.*

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Carey O. Randall
Associate Publisher, Administration

"The Satellite Sky" Update/15

These regular updates to **"The Satellite Sky"** chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2046 9-89 TT
- Cosmos 2047 10-89 PL
- Progress M 8-89 TT
- Soyuz TM-8 9-89 TT
- Gorizont 19 9-89 TT
- Marco Polo 1 8-89 CAC
- Unnamed 9-89 CAC
- TV Sat-2 8-89 KOU

630 to 1,250 MILES

- Cosmos 2037 8-89 PL
- Cosmos 2038-43 9-89 PL
- Intercosmos 24 9-89 PL
- Magion-2 9-89 PL

6,200 to 13,700 MILES

- GPS-3 8-89 CAC

21,750 to 22,370 MILES

- Fleetsatcom 8 9-89 CAC
- GMS-4 9-89 TAN

Deletions

90 to 300 MILES

Cosmos 2007 down 9-22-89	Cosmos 2035 down 8-16-89	Resurs-F4 down 9-14-89
Cosmos 2031 down 9-15-89	Resurs-F3 down 8-8-89	

Launched but not in orbit

90 to 300 MILES

Cosmos 2036 USSR photo recon	8-22-89	down 9-5-89
Cosmos 2044 USSR research	9-15-89	down 9-29-89
Cosmos 2045 USSR photo recon	9-22-89	down 10-2-89
Resurs-F5 USSR earth sensors	9-6-89	down 9-22-89

Inoperative but still in orbit

300 to 630 MILES	21,750 to 22,370 MILES
Cosmos 1791	Arabsat 1B
Cosmos 1814	
Cosmos 1864	
SME	

Forecast

In the Wings . . .

Frequent Flier—For photographer Mark Wexler, it was a dream come true: 30 days of unlimited air travel—free!

Robots in Space—In the future, an astronaut in need of a helping hand may turn to a mechanical one.

The Things in Wings—A guide to the slats, flaps, gizmos, and thingamabobs you can see from your window seat.

The Bicycle-Airplane Connection—Before many early aviators learned to fly they first learned to pedal.

First Light for Hubble—When the space telescope is finally deployed, astronomers hope it will help them find everything from black holes to new solar systems.

Two Accidents, Two Reactions—A look at the investigations of the Apollo 1 fire and the *Challenger* disaster reveal how times have changed for NASA.

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Almost anybody can write a program. But it takes a good team to put together a lot of programs and pieces of hardware and make them work."

—Ken Davis (far right), RAPIER Intelligence Segment (RIS), RIS Program Manager Electronic Systems with (from left to right) Dick Elsey, RIS Technical Staff, Jim Dellinger, RIS Technical Staff, Ray Marion, RIS Technical Staff, Bill Blatchley, RIS Technical Staff, Jim Pierce, RIS Software Development Manager.

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